ИЗМЕРИТЕЛЬНАЯ
ТЕХНИКА

SOVIET INSTRUMENTATION AND
CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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MEASUREMENT TECHNIQUES

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ENSURING A METROLOGICAL BASIS FOR ANALYTICAL MEASUREMENTS

The great plans of technical progress in the USSR are closely connected with the development of the chemical industry. The decisions of the May Plenum of the CPSU Central Committee (1958) on speeding up the development of the chemical industry have also been embodied in the decision of the 21st Conference of the CPSU and the June Plenum of the CPSU Central Committee.

One of the principal means of technical progress in national economy, automation is acquiring a great importance for the development of the chemical industry.

It is only by using instruments and automatic regulators that it becomes possible to provide the most economic use of materials, increase productivity, ensure the fullest and best utilization of equipment, and attain higher quality and uniformity of production.

One of the most important spheres of measurement and control for the chemical industry is the one concerned with analytical measurements, which forms the basis of direct inspection and control of technological processes with respect to the composition of substances (initial, intermediate, and final) and in the long run determines the quality of production. This is the reason why instruments for analyzing the composition of gases, liquids and solids are of outstanding importance for the chemical industry.

Analytical instruments are also of outstanding importance for controlling production in all the branches of industry which involve chemical processes, such as in general and specialized metallurgy, oil refining, coke by-product industry, gas production, the light and food industries, etc., in agriculture, for analyzing the composition of soil, its effective acid and alkali content, and the composition of the air contained in the ground. These instruments are required for analyzing toxic, explosive, and inflammable gases in the pursuit of safety and improvement of the sanitary and hygienic conditions in factories and mines.

At the present in our country there exist many and varied analytical instruments which satisfy modern requirements. The production of gas analyzers has become most widespread. Many types of automatic and semi-automatic gas analyzers are either in production or in the final stages of development. Instruments are being produced for determining the composition of various gases over wide concentration ranges of their components by means of different measuring methods, such as by thermochemical, heat, and electrical-conduction measuring, optical (including interference, photoelectric, and optico-acoustical), magnetic, chromatographic, mass spectrometric and other methods. Instruments are being developed which are based on ultrasonics, ultraviolet, ray selective absorption, radioactivity. Spectrometers using magnetic, nuclear, and electronic resonance are being tried.

A large number of instruments have been designed and are being produced for determining concentrations of hydrogen ions (pH meters)—both the laboratory type and automatic continuous-action ones for industrial use.

Concentrate meters based on various methods, including conduction, dielectric, optical, and polarographic methods, have been developed and are being produced.

Production of analytical instruments, as well as any other branch of the instrument-making industry for that matter, cannot develop without a firm metrological basis, which raises important requirements with respect to the metrological handling of analytical instruments.

It is necessary to speedily produce reference testing equipment and checking methods for analytical instruments, and establish unified methods and criteria for evaluating their errors of measurement, resolving power, selectivity, stability, etc.

At the same time, standards should be set for the production and guaranteeing of pure gases, which would serve as standard substances in checking one of the main groups of analytical instruments, the gas analyzers, and methods developed for producing and analyzing standard gas mixtures.

It is necessary to establish a unified pH scale in instruments for measuring hydrogen ion concentrations, since the absence of such a scale leads to the use of different systems of calibrating the electrode parameters for measuring pH and to different test methods. It is necessary to compile a table of normal buffer solutions for checking pH meters.

It is necessary to initiate metrological investigation of a number of modern analytical instruments including mass spectrometers, chromatographs, and polarographs, all of which have acquired great importance in scientific research and are used on an increasingly wide scale for checking, control, and automation of production.

The institutes of the Committee of Standards, Measures, and Measuring Instruments, the D. M. Mendeleev All-Union Scientific Research Institute of Metrology (VNIIM), its Sverdlovsk branch, and the VNIIK, which are working in this sphere of measurements, have so far paid insufficient attention to analytical instruments.

Thus, for instance, the VNIIM has not as yet completed the development of the reference gas mixing equipment for calibrating and checking gas analyzers, a work which it began as long ago as 1956. Neither has it completed the development of the reference equipment and methods for checking automatic gas analyzers, used for determining small and microconcentrations of gas in binary and multicomponent gas mixtures, a development started by the Institute and its Sverdlovsk branch in 1957.

The Sverdlovsk branch completed this work and produced an apparatus for measuring out gases by dynamic methods, testing this equipment in 1957-1958. Before its final acceptance as a standard, however, it still has to be tried out in calibrating and checking gas analyzers.

The condition and development of the Committee Institutes' work in gas-analyzing measurements was discussed on July 15, 1959 at the technical conference held at the Administration of Measuring Instruments with the participation of representatives from the leading Design Bureaus in analytical instrument-making.

The conference noted the urgent necessity of increasing the volume of metrological work in the sphere of analytical measurements and primarily, in gas analysis, and suggested that the institutes' personnel engaged in this work should be increased.

In order to improve the metrological servicing of industry in the sphere of gas analysis, the conference outlined the following urgent measures: a) to develop methods of checking industrial gas analyzers; b) to establish requirements for pure gases and basic substances for the production of gas mixtures; c) to develop the methods and means for producing standard gas mixtures; d) to compile technical instructions for producing standard gas mixtures and for checking gas analyzers, making the instructions applicable to the basic types of instruments and gases under test; e) to develop a test apparatus for gas analytical measurements; f) to establish the basic metrological requirements for testing of industrial gas analyzers; g) to investigate the metrological characteristics of instruments based on the chromatographic method of analyzing gas mixtures and develop the technique of their testing.

Similar work must be carried out with respect to other groups of analytical instruments such as pH meters, mass spectrometers, and concentrate meters.

The work should be carried out in cooperation with, and the participation of, the institutes of the USSR Academy of Sciences, industrial institutes, universities, and leading design bureaus and factories which produce analytical instruments.

A speedy solution of the above problems is imperative for the fulfillment of the principal tasks in technical progress.

CONFERENCE OF THE WEIGHTS AND MEASURES ADMINISTRATION
OF THE GERMAN DEMOCRATIC REPUBLIC

G. D. Burdin and S. S. Shchedrovitskii

The conference of the Weights and Measures Administration of the German Democratic Republic, held from February 21 to March 3, 1959, was attended, in addition to the personnel of the area inspection administrations of the German Democratic Republic, by leading workers of the metrological services of Bulgaria, Hungary, Poland, Rumania, the USSR, and Czechoslovakia.

The conference was addressed by the president of the German Weights and Measures Administration (GWMA), Prof. Joseph Stanek, who described the organization and structure of the GWMA and pointed out the basic spheres of its scientific and technical activity. Foreign metrologists participated in the discussion, sharing experiences of the scientific and inspection work organization in their countries.

Scientific and technical questions of metrology and inspection in various spheres of measurements were discussed by specialists during unofficial talks and visits to the laboratories of the Central Physicotechnical Institute (CPTI) in Berlin and to the area inspection departments in Fürstenwalde, Ilmenau, Dresden, and Leipzig. The participants of the conference also visited the new construction site of the Central Physicotechnical Institute in the Berlin suburb of Hirschgarten.

The CPTI laboratories conduct work in establishing, preserving, and improving standards of physical and technical quantities, take part in international comparisons, and work on the problems of establishing new methods and means of measuring with high accuracy. The laboratories also check and certify standard measures and instruments of the higher grades for area administrations and departmental laboratories, industrial establishments and scientific research organizations.

A considerable part of the CPTI laboratories' work consists in developing unique and typical model equipment for their own research and for the equipment of the inspection agencies, and in compiling detailed instructions and handbooks on the technical use and application of testing equipment. The prototype equipment which is now being developed for testing standard areometers and an apparatus for automatic testing of clinical thermometers are of special interest. The leading personnel and collaborators of the laboratories systematically visit area inspection administrations, rendering them direct technical assistance and instruction.

Although the CPTI laboratories are fully occupied by direct testing of new types of measures and measuring instruments, the leaders of the appropriate laboratories usually act as chairmen of expert commissions which examine the results of standard tests and applications for assigning to measures and measuring instruments grades of quality.

The collaboration of the CPTI scientific workers with industry is not limited to their participation in the commissions of experts; the CPTI personnel systematically advise industrial establishments on the choice of measuring method and design of instruments and take part in planning design projects.

The high level of the scientific and technical work of the CPTI places it alongside the most advanced metrological institutions of the world.

The central metrological service agency of the German Democratic Republic (GDR) has many interesting peculiarities in its organization and structure.

The CPTI has a main department to which belong the laboratory of the GWMA presidium, the laboratory for foreign guests, and an editorial section.

The laboratory of the presidium is engaged in research work under the direct guidance of scientific workers who are mainly occupied by administrative duties. This arrangement permits the leading workers of the GWMA to contribute personally to the scientific work of the institute.

The centralized editing of all the instructions is important, since it provides a unified content and form to the specifications in the sphere of measurement technology.

The scientific departments and laboratories of the CPTI are thus freed of any administrative functions. The organizational and technical supervision of the area administrations is carried out by department E, and the supervision of the standard tests of measures and measuring instruments is concentrated in department VI, which includes the sections common to all the scientific departments (for instance the chemical laboratory, design bureau, etc.).

The work of expert commissions for different branches of measurement technology deserve attention. With their single methodical leadership these commissions, consisting, in addition to the GWMA specialists, of representatives of industrial and trading organizations, constitute authoritative scientific and technical agencies which can render considerable assistance in developing measuring techniques.

The CPTI is engaged in considerable editorial work. The instructions and specifications on inspection, the rules for testing and checking instruments, instructions on the use of instruments, amendments to the existing rules and regulations, reports on the instruments approved for use in testing, and other official material is published in the form of GWMA leaflets. A separate series of leaflets deals with the report of the GWMA delegations to the sessions of international metrological organizations, to reviews of various spheres of measurement technology and other informative material.

The scientific work of the CPTI is published in scientific and technical journals and the reprints of that work are gathered in a yearly collection of GWMA proceedings. In the collection No. 6 (1958) published in this manner, there appear 15 papers, including one by Dr. G. G. Laport on photoelectric equipment for automatic control with the use of grids and on photoelectric methods of measurement; Dr. E. Padelt's article on a new regulation in the sphere of measuring units and on the basic conceptions of measurement techniques; an article by G. I. Bülmann and M. Schuster on experiments in determining a correction coefficient which accounts for the effect of deformations on the readings of piston manometers by means of capacity measurements of the gap.

Wide perspectives are opening up for the scientific activity of the CPTI in connection with the construction of the new laboratories in Hirschgarten. In their design not only the present level, but also the development possibilities of measurement technology and metrology are taken into account.

The force and hardness measurement laboratory consists of a block of buildings which contains a test hall with a ceiling more than 10 m high, many rooms for the scientific personnel, buildings for the vibration equipment and balancing machines, reference weigh-bridges, etc. The building is provided with cranes, automatic temperature control and other auxiliary equipment.

The low temperature laboratory is equipped, among other things, with chambers for testing instruments under various climatic conditions. The erection of blocks of laboratories in all the spheres of measurement is foreseen, including the measurement of ionization radiations. In addition, special buildings will be erected for an electrical power substation and other services. The construction will take 10 years, yet in the scientific departments of the institute intensive work is proceeding on the production of standard and test equipment for the new laboratories, including, for instance, a standard apparatus for producing forces in the range of 1000 ton-wt, equipment for producing adjustable temperatures in the range of −60 to +100°C, etc.

The organization of the inspection service in the GDR has some interesting peculiarities. Every area inspection administration has a technical test department which includes all the laboratories engaged in state tests of "routine" objects. Such objects consist of devices commonly used in trade for measuring, calculating, etc., including measures and instruments for measuring length, area, volume (including wine and beer barrels), commercial and precision weights and scales, instruments for testing the quality of grain (hondrometers, moisture meters), manometers, and barometers.

Another peculiarity of the GWMA is the specialization of a number of area inspection administrations. In addition to a special laboratory for measuring glass instruments, several large area administrations develop definite branches of the measurement technology, with the view of servicing the industry of the GDR as a whole. Thus, the regional inspection administration in Dresden specializes in checking instruments for linear measurements. It also has a department for checking instruments measuring ionization radiations. The regional inspection administration in Leipzig is a center for checking dynamometer instruments.

The organization and activity of the area inspection administrations is affected by the fact that the industrial establishments are entrusted with the checking of gas, electricity, and water meters, many types of manometric

instruments, and engineering gages. The task of the area administrations in these spheres of measurement is limited to checking reference instruments and equipment and overall inspection.

In the GDR the checking of instruments on the spot is widespread. The area administrations have several trucks at their disposal, which transport equipment used for checking measures and measuring instruments in common use. Such standard equipment is made for each area administration by the workshops of the Suhl area. Special days are reserved for checking instruments on the spot.

The area inspection administrations are located in newly constructed or restored buildings and well equipped with testing apparatus. Each administration has workshops at its disposal which, in addition to repairs of the equipment, produce various devices for making testing easier. Some of these devices originated by innovators are of undoubted value and could be used by our inspection laboratories, for instance, a carriage for loading scales with standard weights, a device for checking measuring efforts, etc.

Many devices for checking conventional measuring equipment are of interest, for instance, an apparatus for checking arms of heavy scales, a stand for checking surveyor's and metal tapes, etc.

Great attention is paid to establishing the required conditions for high-frequency testing of instruments. Premises in which analytical balances and weights, block gages, and other precision measures and instruments are checked have an automatically controlled temperature. A temperature of the order of 18°C is maintained by controlling the general heating system; for the automatic control of temperature in the limits of 20 ± 0.5°C additional gas or electric heating is used and controlled by bimetallic thermostats. In order to provide suitable conditions for checking high precision measures and measuring instruments several area administrations' laboratories will be equipped with air conditioning.

It is common practice to place shock-sensitive instruments on stands and tables equipped with shock-absorbing devices.

Many interesting instruments have been produced by the administration of Ilmenau which specializes in testing glass instruments. It has departments for checking retorts, cylinders, microburets, pipettes, special apparatus for blood analysis and all types of thermometers, from clinical to deep-sea thermometers used in oceanographical research. The number of clinical thermometers checked in 1958 exceeds 6 million.

An examination of the technique of checking measures and measuring instruments in the GWMA shows that considerable time and labor is spent on checking some of the instruments. This is due, primarily, to the low level of mechanization and automation of testing. It should also be noted that insufficient attention is paid in some of the laboratories to safety precautions.

The conference of the German Weights and Measures Administration has shown the desirability of a further development and extension of exchanges in experiences both in the sphere of scientific work and inspection practice.

The communiqué of the conference recommends the holding of similar national metrological conferences not less than once every two years with the participation of foreign guests. It was found advisable to strengthen the scientific and technical collaboration by means of comparing standards, a systematic exchange of scientific literature, specifications, and interchange of specialists from similar laboratories in various spheres of measurement technology.

The foreign delegations noted the high standard of organization and scientific and technical activity of the CPTI and the area administration of the GWMA.

GERMAN WEIGHTS AND MEASURES ADMINISTRATION*.

I. Stanek, President of the German Weights and
Measures Administration

The German Weights and Measures Administration (GWMA) is the central technical agency of the German Democratic Republic (GDR) in the sphere of measurement technology. It is subordinate to the State Planning Commission of the GDR Council of Ministers.

The supervision of metrological work and inspection is carried out by the Central Physicotechnical Institute (CPTI), which is administered by the Presidium of the GWMA.

The CPTI consists of the Presidium department, six scientific departments the production (B), rules (D), inspection (E), economic and financial (H), and the personnel departments.

The Presidium Department and each scientific department is headed by a director.

The basic functions of the Presidium Department consist of: a) the final editing of scientific publications; b) the drafting and final editing of instructions; c) the drafting (in conjunction with department D) of regulations; d) the editing of information leaflets; e) coordinating relations with industry; f) coordinating work in the sphere of standardization and normalization; g) supervision of the Presidium laboratory work and that of the laboratory for the CPTI guest specialists; h) registering standards.

The remaining scientific departments consist of main laboratories, which in turn are subdivided into laboratories. Below is given a brief description of the main laboratories' tasks.

The scientific department I has five main laboratories whose task is to work on all the problems connected with mechanical units: main laboratory 1 deals with linear and angular standards and accurate measuring equipment in engineering; main laboratory 2 — with force and hardness standards and measurements of mechanical vibrations; main laboratory 3 — with measurements of volume; main laboratory 4 — with measurements of density and viscosity; main laboratory 5 — with measurements of mass and determination of humidity.

Scientific department II works on all problems of electrical and magnetic measurements and electro-acoustical problems. This is the largest scientific department of the GWMA and consists of seven main laboratories: main laboratory 1 deals with electrical units; main laboratory 2 — with magnetic units; main laboratory 3 — with technical problems of testing and checking standard measures in electrical engineering; main laboratory 4 deals with high-frequency problems and with obtaining units of time by means of electrical methods; the high-frequency research includes the microwave range. Main laboratory 5 deals with electrical standards for audio and ultrasonic frequencies; main laboratory 6 — with pointer instruments and meters; main laboratory 7 — with dielectrical properties of materials.

Scientific department III deals with all questions connected with measurements of pressure, temperature, and other thermotechnical quantities and with instruments used in this connection, as well as with research in a number of associated problems such as measurements of thermal conductivity. This department has four main laboratories: main laboratory 1 deals with calorimetric standards; main laboratory 2 — with low temperature standards; main laboratory 3 — with temperature standards; main laboratory 4 — with pressure standards.

The sphere of scientific department IV includes all problems connected with methods and instruments for measuring optical quantities as well as photometric measurements and the determination of optical system parameters for photo- and cinematography. The department has three laboratories: main laboratory 1 deals with light units and spectroscopic standards; main laboratory 2 — with wave optics and standards for photo- and cinematography; main laboratory 3 — with mathematical problems for the whole of the institute.

Scientific department V covers the sphere of ionization radiation measurements and develops instruments used for this purpose. Both x-ray and radioactive substance radiations can serve as sources for this purpose. In the future, measurements of nonradioactive isotopes by means of mass spectrometry will be conducted in this department. The work of the department was originally founded on measuring x-ray radiations, especially for therapeutic and diagnostic purposes and for protection against radiation. It is planned to divide the department into

three main laboratories: main laboratory 1 for measuring x-ray radiations; main laboratory 2 for radioactive emissions; main laboratory 3 for mass spectroscopy.

The task of the scientific department VI consists in making routine measurements in the sphere of measurement technology. This department thus fulfils the GWMA functions in measuring materials and production in the whole of the instrument-making industry. The work of the department is distributed among 28 commissions according to the nature of measurements performed, with their personnel appointed by the GWMA Presidium. Chairmen of the commissions are, as a rule, leaders of the main CPTI laboratories in the corresponding fields of measurements, and their membership includes chairmen of Government organizations, manufacturing plants, consumer establishments, and trading organizations.

On the basis of test results the commissions evaluate the quality of production. The grading of products according to their quality is carried out on the basis of regulations and is confirmed by assigning a grade to the article. The testing of instruments is carried out by the GWMA and is entrusted either to the CPTI or the area laboratories according to the intricacy of the measurement. On the basis of the experience obtained from routine testing, scientific department VI carries out inspections and makes, in conjunction with the industrial authorities and administrations, proposals for the improvement of the quality of production. These proposals are included in the steps taken to increase the efficiency of production, raise the technological level, and improve the quality of the goods. In this connection, the problems of standardization and the use of modern materials are always taken into account.

Department VI is in charge of the chemical laboratory, the laboratory for automation instruments, and the design bureau.

Department D is in charge of the legal questions and problems of technical and scientific cooperation on the international scale. The department supervises the library and the archives. The personnel of this department edit the technical documents and translate the scientific and technical articles and instructions. All the GWMA sections connected with the distribution of technical literature come under this department.

Department E is in charge of all the area inspection administrations. The efficient organization of inspection had a very good effect on its own development and that of the socialist economy.

According to the existing regulations each region of the GDR must have a regional inspection administration. The regional administrations are subdivided into districts whose number is determined by local conditions. At present, administrations have been set up in 15 regions. The Gera region which has not an administration of its own, is served by the Suhl region administration with its center in Ilmenau. In addition, there is a specialized administration for testing glass instruments (in Ilmenau).

The regional inspection administrations play the part of state metrological agencies in the corresponding regions. They are run by workers trained in testing techniques, in the majority of cases by experienced engineers, who are responsible for the corresponding sections of the general GWMA plan.

Before 1952 the regional administrations were engaged in the main in testing weights, scales, and instruments for measuring length and volume used in trading. This could not satisfy the growing demands of the national economy. Therefore, since 1952 inspection was directed towards servicing measurement equipment in industry. By 1958 a plan was drafted for development of testing technology. According to the plan the inspection agencies were entrusted with the following basic tasks.

1. Ensuring the efficiency of measuring instruments in all the spheres of national economy and in the health services.

2. Supervising the instrument-making and repairing plants, administrative inspection laboratories and agencies which use measuring instruments, in order to ensure a technically efficient condition of the measuring equipment in the GDR, and exercising control over these organizations.

The laboratories existing in the inspection departments are unified into sections. In all the regional inspection administrations four sections are compulsory and they deal with the following: 1) inspection; 2) instruments for measuring length and instruments for measuring dimensions in engineering; 3) instruments for measuring force and hardness; 4) electrical measuring instruments.

Since the GDR covers a relatively small area, it is possible to entrust certain laboratories, which have elaborate equipment, with servicing nearby regions in that sphere of measurements.

The specialized administration for measuring glass instruments and measures has departments for instruments measuring volume, measuring density and viscosity, and temperature.

Some of the administrations are developed as basic ones for a given sphere of measurement . The task of basic laboratories is to assist the development of the corresponding spheres of measurements in the neighboring administrations.

The scientific supervision of the inspection administrations, including the checking of the higher grade instruments, is carried out by the scientific departments of the CPTI.

Only 13% of the instrument inspection is carried out in the regional inspection laboratories; 21% of the instruments are checked by request and 66% on the spot.

Once every two years the regional inspection administrations organize, in all the towns and villages, inspection days, and send a crew of inspectors to the appointed place in a fitted-out truck.

At present the GWMA is revising the technique of carrying out such inspections owing to the changed conditions in agriculture of the GDR. After 1960 it is planned to introduce mobile inspection laboratories on specially equipped buses and trailers.

Considerable attention is paid to the standardization of the testing equipment. Recently 28 regulations on the standardization of the test laboratories' equipment were issued. These regulations contain detailed instructions which are useful not only for the GWMA organizations, but also for industrial plants.

Since 1956 each regional administration has a general inspection department. For such inspection work at industrial plants, it is necessary to have trained engineers and technicians, who are not as yet available in sufficient numbers. Although at 1000 industrial establishments a yearly detailed check is made of all the measuring equipment from the bench to the instrument store, yet their test laboratories and the times and methods of checking are subject to general inspection. If it is found impossible to check the instruments on the spot, the establishment is instructed to send the instruments to the regional administration for inspection.

The initial and routine checking of standards, measures, and measuring instruments is planned by the GWMA and controlled by means of a reference index.

According to the existing regulations, the power supplying organizations are responsible for the accuracy of electricity, water, and gas meters which are periodically checked in the laboratories of these organizations.

The regional inspection administrations are responsible for the power-supply establishments fulfilling their obligations with respect to the time of periodic checking of meters, and for their laboratories having the required equipment and complying with established testing regulations.

In certain instances the gas meters are checked in situ by means of special standard meters.

Since 1945, new buildings for four regional administrations were completed, six administrations were extended, the construction of buildings for three administrations and an inspectors' school for 20 persons has begun.

The development of the regional inspection administrations since the establishment of regions is illustrated by the following figures. The number of inspected instruments has increased by 39%, the sums collected by 20%, and expenses (they amount to 24% of the income) by 68%. The cost of capital construction and equipment rises yearly by about 7%. The personnel has increased by 43% and their average wages by 12%.

In 1957 the administration carried out 4726 tests on standards, measures, and measuring instruments, 786 routine and 2201 other tests. The number of instruments checked exceeds 10 million . The number of checked glass instruments has risen especially rapidly from 6773 thousand in 1956 to 7129 thousand in 1957. The number of checked clinical thermometers increased in the year by 318 thousand .

All these figures show the extent of development of measuring technology in a socialist state. The economic development of a country depends to a great extent on the condition of the measurement technology, and the high level of the State Metrological Service is a convincing proof of the stability of the German Democratic Republic's national economy.

In department H all the economic and financial problems are dealt with.

Department B is in charge of capital construction and supervises production (workshops, electricity, water, and gas supplies).

In order to obtain the scientific personnel for the CPTI laboratories and the administrative inspection departments, the GWMA recruits graduates from higher technical schools and universities. It is proposed to have in each regional administration a technical head with the required scientific qualifications.

Among the tasks facing the GWMA is the drafting of rules for bringing order into the measurement technology. The GWMA issues information leaflets with instructions of interest to the personnel of the Administration and to the industrial personnel and workers in other branches of the national economy. The leaflets also contain instructions for the proper use of the measuring equipment and the description of the measures and measuring instruments approved for state testing.

In 1958, 68 information leaflets were issued and dispatched not only to the regional administrations, but also to all interested organizations in the GDR and abroad, especially to the corresponding organizations in the socialist countries. Collections of scientific works, compiled from the articles written by the GWMA collaborators in technical journals, were also issued.

This is, in general terms, the structure and organization of the German Weights and Measures Administration.

SCIENTIFIC WORK CARRIED OUT BY THE CENTRAL PHYSICO-TECHNICAL INSTITUTE OF THE GERMAN WEIGHTS AND MEASURES ADMINISTRATION IN THE SECOND FIVE-YEAR PLAN*

G. G. Laport, Vice-President of the GWMA, and E. Padelt,
Director of the Presidium Department of the GWMA

The most important events in the work of the German Weights and Measures Administration (GWMA) presidium were the construction of the new buildings for the Central Physicotechnical Institute (CPTI) and the transfer of testing to the regional inspection administrations and industrial establishments, in order to free the CPTI laboratories for research in special scientific problems; in addition, a design office was established in the CPTI and the training of laboratory physicists renewed.

The training of a good scientific and technical personnel and engagement of experienced and scientifically qualified collaborators has not yet attained the required proportions. All the scientific sections experience a shortage in trained personnel; in the majority of laboratories there is only one scientist at work.

The Scientific Department's laboratories have systematically advised the instrument-making plants, especially on questions of location of the testing and adjusting equipment and on the organization of laboratory premises. In many cases scientific workers go out to the factories in order to explain certain questions directly on the spot (for instance, an efficient method of placing the testing equipment, on the equipping of the testing benches or departments, and on the organization of technical inspection departments), or to advise on the method of eliminating apparent defects. Thus, the scientific workers of the CPTI play a leading part in improving the quality of production and make a considerable contribution to the development of the national economy of the German Democratic Republic.

The work of the Scientific Department I deals with the entire sphere of mechanical measurements.

Linear Measurements. One of the tasks of the linear measurements laboratory was the development of an instrument for measuring the internal helix angle; the instrument is now being constructed. In addition, the laboratory must produce instruments of the highest sensistivity for checking graduations, determining the coordinates

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in the vertical plane (cathetometer) with high precision, and for checking the pitch of gear wheels. It also had to test and bring into use a comparator for comparing end and line measures.

Measurements of Volume. In the first place should be noted the development of a method for testing stationary large-consumption gas meters, which are becoming increasingly important in view of the rise in the industrial consumption of gas. One of the important problems consists in developing a method of checking constricting devices and gasometers in a shorter time than usual. Research is also conducted on methods of checking rotating gas meters by means of standard orifice plates.

Measurements of Mass. The laboratory for measurements of mass, which has contributed a lot to the improvement and increased production of laboratory balances in the GDR, has further developed the methods of testing laboratory balances and precision weights. It was also necessary to conduct routine tests of scales made in the GDR and reduce the number of types in use. Research on the methods of determining humidity in grain was carried on intensively.

After the relation between the readings of the electrical humidity meters and the grain's origin, the type of fertilizers used, and the kind of artificial drying employed had been established, steps were taken to extend the range to measurements of relative humidity over 20%. As the result of this work it will soon be possible to measure humidities up to 30%. It was necessary to compare various methods of determining humidity, by means of drying and other methods, in order to determine which were the best to use for various humidity contents. It would appear that a new basic method of measurement should be developed which would conform to the knowledge available to us at present.

Standard Instruments for Measuring Force and Hardness. The loading device of the standard equipment for producing forces up to 1,000,000 kg-wt, whose development had started as early as 1954, was modified in such a manner that its loading can be made without shocks or swinging of loads. The final testing of the equipment will only be possible, however, when it is eventually installed in the special hall of the new laboratory in Hirschgarten.

The development of a method for measuring machines with a pulsating load and the construction of an appropriate measuring instrument, based on the electrical and electrooptical principle, has not yet been completed, mainly due to the lack of suitable premises.

After numerous experiments, the construction of a standard instrument for determining macrohardness by the Vickers method with a load of 100 kg-wt has begun. The production of a standard instrument for small loads has been completed. Preliminary experiments for determining the absolute value of gravitational acceleration in vacuum was carried out in other institutes (for instance, in the Geophysical Institute of the German Academy of Sciences in Potsdam, VNIIM in Leningrad, and Physicotechnical Institute of the FGR in Brunswick). In addition, international comparisons were made of standard plates and normal samples of hardness, and cylindrical tensile dynamometers for loads up to 1,500,000 kg-wt are being developed.

Measurements of Density. The work on improving and simplifying the method of checking areometers has been successfully conducted, and the multiscale areometer, produced in 1955, has been recalibrated. In addition, the equipment for testing reducers has been reconstructed and the error in checking reducers with a ratio of 1 : 100 decreased to 0.5%. Special attention was paid to investigating the balance equipment in order to avoid the effect of interference.

Scientific Department II conducts electrical and magnetic measurements. Owing to the wide scope of this department the lack of appropriate premises has greatly affected the work of the department. It is true that it was possible to construct a soundproof chamber for acoustical measurements, but no further additions to the department are contemplated.

Standard Resistors. Following the improvement in recent years and the industrial application of the equipment for testing the life of heater elements, preparatory work has started on the development of an ampere balance. Work has started on the improvement of a compensating device for accurate measurement of the emf of standard cells, and also on the development of a cell of the order of 100 mv and of a portable single-bend standard cell.

The comparison of standard cells made by the International Weights and Measures Bureau showed that the variation of the emf, as compared with the value determined in the last international comparison tests, are smaller

than 10^{-6}. In the large CPTI stock of standard elements the damaged ones were replaced by new ones made in 1954, and the stock increased to 68. Four normal elements were presented to institutes of friendly states. Two elements were sent to Chile as the basis for a national standard voltage unit.

For the determination of the absolute unit of resistance much research work is required, some of which has to be conducted by other scientific establishments. This work will serve as a basis for the classification of standard and operational resistors.

Standard Capacitors and Inductors. Torsional oscillations of quartz rods for crystal clocks were investigated under piezoelectric excitation. A 500 kc Schering bridge was reconstructed and a method of speedy determination of very small capacitances with an error of 1% by means of the existing equipment was developed. A speedier method was developed for checking switched capacity boxes, and the alterations required for this purpose made in the corresponding instruments. Various large mutual inductance standards were investigated and the relation of the capacitances of both their halves determined.

Systematic research was made of the possibility of using twin conductor lines as standard measures of inductance and loss in the high frequency range. A Maxwell bridge for measuring inductance and a resonance bridge for measuring inductance and resistance were successfully improved.

Magnetic Measurements. The effect of joints on loss measurements when electrical and transformer steels are remagnetized was investigated and the technique of ballistic measurements of the demagnetization curve of permanent magnets was developed. In this connection it was found possible to simplify considerably the method of checking fluxmeters owing to the establishment of an appropriate standard mutual inductance and it was possible to improve the method of direct ballistic measurements of the field strength of permanent magnets and of ballistic measurements of magnetic fields.

Electrical Pointer Instruments. Experiments were conducted on stabilizing the frequency of an ac generator by stabilizing the speed of the driving motor, and resonance curves of two reeds of a frequency meter were obtained. The possibility of using dc rectifiers as sources of voltage supply for measurements by the compensation method are being investigated, and a compensation apparatus was developed especially for testing electrical pointer instruments.

Electricity Meters. Preliminary investigations were carried out for developing a method of accurate measurements of ac electrical energy by means of "balancing ac and dc electrical energy."

Owing to the lack of facilities for the numerous investigations in hand, the equipment made available by the transfer of the testing of electrical meters to the power supply organizations was installed, tested,and put into service at the CPTI laboratories.

AC Measurements. An instrument for measuring high ac and dc voltages up to 500 kv enclosed in a gas pressure chamber, and another one for measuring ac and dc voltages with respect to ground up to 500 kv with a revolving segmented cup are as yet in the development stage.

A new method of measuring accurately high phase voltages with an error not exceeding 0.2% was developed. New inductance potential dividers, which in the operating ranges allocated to them can serve as standards of high precision, have been developed for ac bridges and compensation circuits. The error of a 2.5 meg potential divider, which has a voltage controlled externally by means of a grounded screen grid, was determined with respect to various factors. Preliminary tests showed the possibility of using the differential ring method for testing wide-band transformers.

Standard instrument for high frequencies. The work on precision high frequency voltage and current measurements was continued, but the basic research on measuring and testing methods for ultrashort-wave measuring and testing instruments has not yet been completed. The effect of master oscillator connecting circuits on the frequency stability of quartz crystal clocks was investigated by means of various special circuits. Some of the CPTI crystal clocks were reconstructed according to the latest data or their circuit design was changed. New types of thermostats were tested. The receiving devices for reference frequencies have been modified for comparison with the standard 1 kc frequency of the Geodesical Institute in Potsdam and also with 60 and 200 kc carrier frequencies of Rugby and Droitwich,respectively. Standard frequencies have been transmitted since 1956 over the German Broadcasting Station and post administration channels.

Insulation Materials Measurements. An apparatus for testing ϵ and tanδ measuring instruments has been constructed. A chamber for measuring liquid insulating substances has been developed. New synthetic materials developed in the GDR have been tested.

Standard Instruments for the Ultrasonic Range. Initial tests were made for developing methods of measuring power in ultrasonic circuits with low or very high amplitudes of oscillations as well as modulated oscillations. Methods for testing marine ultrasonic pulsed echo instruments were developed. Methods of sound analysis were investigated and work on the construction of an apparatus for measuring standard tape recordings and tuning forks has commenced.

Time Laboratory. The work on the development of an automatic apparatus for checking clocks by means of an optical device has been completed. At the same time an instrument for checking clocks by means of an acoustical device has also been developed. An apparatus with an astronomical pendulum clock as a standard has been ordered for the test laboratory in Stralsund. One of the two instruments for testing stop watches has been handed over to the inspection administration of the Magdeburg region. In addition, methods and the equipment for testing hydrocompasses under conditions occurring in their application were developed.

Scientific Department III deals, in addition to general temperature and pressure measurements, with special problems in these spheres. Experimental work is concentrated on studying standard instruments and routine measurements. The number of other types of measurements is steadily decreasing owing to the transfer of many of its functions to the newly formed laboratories.

Pressure Standards. The relation of rhenium alloy wire resistance to high pressure was investigated experimentally. The equipment with a manganin manometer has been improved. Work was started on the development of a standard barometer.

Low Temperature Measurements. New instruments for measuring low temperatures were developed and tested. For the purpose of acquiring experience, some of the laboratory workers were sent to the Kamerling-Onnes laboratory of the Leyden University (Holland). An instrument for setting various temperatures was put into operation.

Temperature Standards. Basic determination of the solidification point of gold was carried out. Systematic study of mercury contact thermometers was carried out, a new platinum resistance thermometer is planned and preparations are in hand for making a new gas thermometer which has no dead space. Research has been carried out on determining the Benedix effect in mercury, on measuring the relative bulk expansion coefficient of gallium and its alloys,and on developing an electronic temperature control. Work was done in compiling conversion tables from the platinum thermometer scale to the international temperature scale in the range of 0-630°C. A method of checking thermocouples by the gold temperature point was developed. Ageing of standard thermometers and checking of calorimetric standard thermometers against resistance thermometers in the range of 0-40°C was carried out.

Pyrometers. The standard reference glowing filament pyrometer was calibrated against the gold temperature point. By means of it, secondary standard pyrometers were checked and they were used in turn for checking standard instruments.

Viscosimetry. Preparatory work for developing an absolute viscosimeter was completed. For further work in viscosimetry it was found necessary to revise the standards and redetermine the instrument's constants.

Determination of the Thermal Conductivity Coefficients. After having improved the standards and test instruments for determining the coefficient of thermal conductivity, it was found possible to commence the determination of the thermal conductivity of vapor in relation to pressure and temperature. A new apparatus and various special devices were constructed for the catathermometer, for instance,for determining the calorific value. A new metal calorimeter has been designed for determining the specific thermal capacity of solids. A device for measuring heat flow has been constructed as well as an apparatus for its testing.

Scientific Department IV deals with optical measurements.

Photometry. An apparatus has been constructed for automatic determination of the spectral efficiency of color filters. Work was conducted on the construction of standard lamps for measuring the intensity of light, luminous flux and color temperatures, as well as on the development of methods for determining the sensitivity of photographic layers (including color sensitivity).

Photo- and Cine-Optics. Interferometric research was carried out with the object of improving the interference pictures, and a method was developed for determining very small displacements. Focal distances can be measured with a determined accuracy by means of the new focimeter.

Optical Radiations. A spectral measuring apparatus with a double monochromator is being constructed. Preliminary tests were made for the construction of bolometers which use carbon and thermocouples with films produced by means of evaporation.

Polarization and Interference. Work on constructing a technically acceptable apparatus for a flatness standard has not yet been completed. A measuring device for determining by photoelectric means the rotational dispersion in the ultraviolet range has been constructed, but the device still requires certain improvements. The production of a standard set of quartz plates will improve the quality control in the sugar industry of the GDR.

Scientific Department V for measuring ionization radiations was founded in 1956.

X-ray Radiations. A model of an x-ray spectrometer-analyzer was made. An electrostatic high-tension vacuum tube device designed mainly for measuring dc voltage was improved.

INSPECTION LABORATORIES OF THE GERMAN WEIGHTS AND MEASURES ADMINISTRATION

G. V. Lirs, Head of the German Weights and Measures Administration (GWMA) Inspection Department

The regulations in force in the German Democratic Republic (GDR) stipulate the following forms of State supervision over measures and measuring instruments.

All standard measures and measuring instruments used in the GWMA agencies for checking other measuring instruments are subject to State guarantee.

The following instruments used in the GWMA agencies are subjected to State inspection: clinical thermometers; commercial instruments used for determining lengths, areas, and volumes; weights, scales; hondrometers and humidity meters, used for measuring grain; instruments for determining volume and density such as graduated tanks, measuring glasses, calibrated pipettes, burets, hydrostatic balances and areometers, beer and wine barrels and pharmaceutical balances.

Gas, water, and electricity meters and instrument transformers are subject to State inspection in the power supply organizations' inspection points recognized by the GWMA.

All instruments used for physicotechnical measurements in production or checking of goods are subject to administrative inspection at factory inspection points of GWMA laboratories.

The inspection is carried out by the GWMA agencies of all instruments which are subject to State guarantee, state or administrative inspection, and to devices used for grading by length, area, volume, or weight.

Routine state testing is carried out on all new types of measuring instruments and the quality of the current production in instrument-making plants is controlled by systematic check tests.

The main burden of State supervision over measures and measuring instruments is carried by the area inspection administrations of the GWMA.

The size and structure of these administrations is determined by the tasks assigned to them and the economic peculiarities of the regions they serve. Purely agricultural areas possess relatively small administrations amounting to some 20 members, whereas in industrial areas their number reaches 70. The specialized administration for

checking glass instruments has a staff of 180 located in Suhl where the main glass production is concentrated. In all the 15 regional and specialized administrations of the GWMA 765 people are employed.

Each administration consists of three sections: the economic, production, and supervisory inspection sections. The laboratories which belong to the administration are formed according to their specialization into inspection, precision and linear measurement, force and hardness measurement, and electrical measurement departments.

Permanent branches of the regional inspection administrations operate in large towns.

Some of the inspection laboratories which are equipped with particularly valuable instruments carry out tests for the neighboring regions.

Laboratories which are most suited by their equipment and regional characteristics become principal laboratories. They are favored both with personnel and equipment in order to make them capable of developing the appropriate branches of the measurement technology in other regions as well as in administrative test and measurement laboratories.

Great attention is paid to standardization of the equipment of inspection laboratories. Recently 28 instructions were issued in which the test equipment was specified in great detail. These instructions are used not only for supplying the new GWMA laboratories, but also for organizing administrative inspection of industrial establishments.

Scientific direction of the activity of inspection laboratories, including the comparison of their measures and measuring instruments with those of higher grades, is carried out by the scientific departments of the Central Physicotechnical Institute (CPTI).

By means of mutual visits, exchanges of experiences, and combined work in commissions, a close contact is maintained between the CPTI departments and the regional inspection laboratories.

Each regional administration has a leading body consisting, in addition to the administration head and the chief engineer, of the party secretary, trade union chairman, heads of the various services, departments, and laboratories, as well as the most active personnel.

This body of members discusses problems of the development of the administration, analyzes the results of the work done, proposes measures for the improvement of leadership, technological organization, planning of inspection work, etc. At the same time the principle of personal control and responsibility of the head of a department is fully preserved.

Each quarter, a statistical report with an analysis of the work of the administration is submitted.

The materials contained in these reports are supplemented by the systematic visits paid by the members of the inspection department of the GWMA to the various districts and the quarterly conferences of the heads of district administrations and the workers of the GWMA held in turn in all the districts. These conferences discuss the main technical and organizational problems of the inspection administrations and arrive at the required decisions.

In order to ensure a uniform development of the administrations, every six months a conference of the heads of services and departments of the regional administrations is held.

The head of the economic service is appointed by the GWMA president and is responsible for the financial discipline of the administration. The financial activity is based on this rule: the collections must at the very least cover the administrative expenditure (excluding capital expenditure).

The production service is based on the small workshops which exist in all the administrations and which perform the pressing repairs of the testing equipment and automobiles. Some of the administrations possess larger workshops. The central workshops of the entire inspection service are located in Ilmenau, which provides the needs of the regional administration, the specialized administration for checking glass instruments, and makes test equipment for other regions (primarily the standardized set of mobile test equipment for travelling inspection branches).

The regional administrations in Dresden and Leipzig also have well-equipped workshops.

The inspection service supervises the measuring equipment in trade, the health services, industry, and research establishments.

During overall inspections of industrial establishments, measuring instruments are checked, the instrument testing premises are examined, and the methods and frequency with which the instruments are checked in the factory are ascertained (agreements on overall inspections have been concluded with the largest chemical plants, railroads, communication services and other organizations which process a great many measuring instruments).

The inspection report is sent to the director of the plant, the head of the Technical Inspection Department, and to the organization which is in charge of the establishment in question.

An agreement is concluded with all the organizations on the manner of checking their standard instruments in the GWMA laboratories.

The supervisory inspection service of the regional administrations exercises control over the activity of the electricity, gas,and water supplying organizations, which are responsible for the accuracy of the electricity, gas, and water meters in use. It supervises the methods and frequency with which the meters are checked by the supply organizations, checks the fulfillment of the conditions which are stipulated for the recognition of the departmental control points, and in certain instances checks the meter readings insitu by means of special portable standard meters. Such supervision of meters has justified itself completely, since it permits the combining of checking with adjustment and avoids duplication of work in the establishments and inspection agencies.

At present there are 40 administrative points for checking electricity meters, 68 for gas meters, and 250 for water meters.

In the early years of the GDR metrological service the testing of several intricate instruments was entrusted to the best-equipped industrial laboratories. As the regional inspection laboratories developed, the industrial laboratories were freed of this task. The best industrial laboratories are still allowed to check their own standard measures and measuring instruments against reference instruments of a higher grade guaranteed by the GWMA.

The inspection departments of the regional administrations include laboratories for checking measures and measuring instruments used for measuring length, area, and capacity (including wine and beer barrels), laboratories for checking commercial scales and weights, and measures of grain.

The administration has control points at instrument-making plants of the region, breweries, and large towns, and organizes once every two years inspection days in every town and village of the region.

At present the GWMA is preparing a change in the technology of mass inspections. Special mobile laboratories in trailers attached to trucks are being used during inspection days. Instead of individual repairs of weights, the defective weights are exchanged for good ones. The faulty weights are repaired and checked at the regional department more efficiently.

The plan for the development of inspection provides for greater mechanization and, in particular, for the use of modern weighing trucks for checking automobile weigh bridges and 60 ton railroad weigh-checking platforms.

The department for linear measurements has a laboratory for checking standard measures, another one for industrial measuring instruments,and yet another for gear measuring instruments. These departments only exist in 9 regions, but by 1965 they will also be established in all the remaining regions. It should be noted that for production measuring instruments no fixed frequency of checking has been stipulated. Inspection intervals are fixed by the plant to which the instruments belong, but must not exceed one year.

The laboratories of the regional administrations primarily service establishments which have no departmental laboratories. The test laboratories are supplied with the most up-to-date equipment produced by the national industry of the GDR. Suffice it to say that the laboratory for checking reference instruments of the Dresden regional administration has two new interferometer comparators.

Measurements of force and hardness have not yet been fully developed in regional administrations. The development of this sphere of measurements commenced in the Leipzig regional administration where the largest manufacturing plant of these instruments is located. This administration has a reference testing machine for checking standard dynamometers up to 100,000 kg-wt and standard hardness instruments for checking gage blocks.

In six of the regions laboratories are being equipped, which will in one year's time measure hardness gages, dynamometers, and testing machines up 300,000 kg-wt.

Testing of special measuring instruments used in the textile industry is done in the regional administration laboratory of Karlmarxstadt, which is in the center of the textile industry.

State testing of electrical measuring instruments was started in 1949. The establishment of electrical measurement laboratories in the regional administrations took a long time owing to the difficulties in finding trained personnel, premises, and equipment. Nevertheless in six regional administrations, laboratories have already been set up for testing ac and dc electrical measuring instruments of all grades, as well as electricity meters.

The relatively small area of the GDR made it possible to test standard resistors, ohmmeters, precision bridges, standard cells, and instrument transformers in only three of the regions.

A laboratory for measuring standard capacitors and inductors is being set up in Potsdam, and for testing frequency meters and tachometers, in Dresden.

In the Halle regional administration, which is in the center of the chemical industry, special laboratories are being set up for actively assisting the program of an intensive development of the GDR chemical industry. For this purpose a new building has been constructed in which a laboratory for determining calorific properties will be immediately established.

In Dresden, where the largest plant producing radiometric instruments is located, a laboratory for their testing has been set up. The organization of such laboratories is also planned for Leipzig, Magdeburg, and Schwerin.

A special place is occupied by the specialized administration of Ilmenau for checking glass instruments. This administration includes a technical office whose aim is to ensure a continuous flow and improvement of the mass-production testing of instruments as well as of special tests of instruments.

This administration is developing rapidly and has achieved considerable success in the improvement of testing methods, training of specialists and, especially, in improving the quality of the instruments produced by the establishments to which it caters.

All the inspection administrations are badly in need of trained personnel.

In 1959-1965 the inspection agencies are due to receive 152 young specialists from universities and higher technical schools.

It is also necessary to raise the qualifications of the inspection agencies' personnel. At present the qualification of a senior tester is attained as the result of a two-year training course run according to an approved manner and syllabus. A similar training, but on a higher level, is required for a test engineer. The following subjects are studied: social science, mathematics, measurement techniques, testing technology (in the appropriate sphere of measurements), legislation in the sphere of metrology. The students are allowed one day off per month for studying.

The final examinations, both oral and written, are conducted by a commission under the chairmanship of the GWMA president.

A similar type of training is used for the industrial inspection personnel. With the opening of a special school, training of engineers and metrologists for the inspection service will be greatly speeded up.

The 1959-1965 plan for the development of the inspection service reflects the growing demands of the socialist national economy of the GDR.

The plan provides for a further improvement of the work of the administrations, modernization of the laboratory equipment, mechanization of testing, erection of new buildings, and reconstruction of some of the existing ones.

EXPERIENCE IN ORGANIZING BASE LABORATORIES FOR SUPERVISING MEASUREMENT EQUIPMENT

D. M. Sizov

As the result of the reorganization of industrial and construction administrations, the need has arisen for the forming in the industrial establishments of service inspection agencies which could fully satisfy the greater demands of the Sovnarkhoz*plants for efficient supervision over their measuring equipment and its effective repair.

On the advice of the Zaporozh'e State Inspection Laboratory of Measuring Equipment the Sovnarkhoz organized such base laboratories in large industrial centers of Zaporozh'e, Melitopol',and Berdyansk, in the Zaporozh'e plant of thermotechnical instruments, the Berdyansk "Mayday" plant of linear and angle measuring instruments, and the "Dneproénergo" group of factories of electrotechnical measuring instruments. At the automobile repair plant a base laboratory is being organized, which will supervise the use of gasoline meters and pumps and repair them.

Difficulties were encountered in organizing these laboratories owing to the lack of premises, trained personnel, and standard test equipment. However, these difficulties were overcome. The work of the "Mayday" plant base laboratory can serve as a good example. A special, completely satisfactory building was constructed for it; the laboratory has adjusting, gage, standards, routine measurements,and other departments. The laboratory has all the required measuring equipment, including a measuring machine IZM-10, universal microscope UIM-21, interferometer PIU-2, optical dividing head ODG, horizontal and vertical telescope calipers, and sets of grade III block gages, with glass plates and all the required accessories.

The supervision of the measuring equipment and its repair is carried out according to a schedule approved by the Zaporozh'e State Inspection Laboratory of Measuring Equipment and the nine plants served by the base laboratory.

This arrangement resulted from an accurate listing of all the gages and measuring instruments at the said plants thus providing the possibility of estimating the amount of work available for the base laboratory and determining the required personnel.

The laboratory estimated and submitted for approval the cost of maintaining the equipment of the plants. In addition to inspecting and repairing the measurement equipment, the base laboratory advises the factories on various questions of measurements and the use of instruments, and sometimes lends the plants its own instruments for making certain intricate measurements.

The base laboratory has, with the active cooperation of the Zaporozh'e State Inspection Laboratory,developed and brought into service in the plants devices for checking universal microscopes, dial inside calipers, large size micrometers, lever-type caliper gages, devices for simultaneous checking of two clock-type dial gages, etc.

The base laboratory has greatly assisted the "Mayday" plant in discovering the reasons for waste.

The personnel of the base laboratory, competing for the title of the Communist Production Crew, undertook to introduce modern measurement techniques at the plants serviced by it.

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* Sovnarkhoz = Council of National Economy —Publisher's note.

LINEAR MEASUREMENTS

AN OPTICAL METHOD OF CHECKING KINEMATIC ACCURACY
WITHOUT A PROTOTYPE

V. P. Korotkov

The most important factor which determines the operational qualities of any mechanism is its kinematic accuracy, i.e., the accuracy with which the mechanism reproduces a given law of movement in the absence of external interference.

One of the basic requirements of the means and methods of controlling kinematic accuracy is the provision of direct observation of the moving object without stopping it for measurements, thus making the requirement difficult to attain. Hence, in avoiding this requirement, the accuracy of separate (discrete) positions of the mechanism is often checked by stopping it, and the results of such a control are taken as indications of its kinematic accuracy.

The checking of kinematic accuracy of any mechanism amounts, in the long run, to comparing the actual and the given laws of motion of the mechanism. The methods of producing and comparing the given and the actual laws of movement may be quite different. Usually a standard detail is employed for this purpose (a kinematic pair) or a standard mechanism which is a prototype of the controlled object.

The method of controlling kinematic accuracy by means of a prototype has several important disadvantages: the high cost of making a prototype for the limited range of its application; a limited accuracy in making the prototype which provides an approximate reproduction of the law set for the object; the appearance of considerable forces in the measuring circuit, and hence its distortion (due to the necessity for the displacement by the sample mechanism of comparatively large masses, for instance, the measuring carriage or the carriage holding the product).

There are other disadvantages connected with the use of a prototype.

It is better to control kinematic accuracy by means of a nonprototype method which avoids the necessity of using sample products, kinematic pairs, or any other prototypes of the object under control.

Below we describe the theoretical basis of an optical method developed by the author for controlling kinematic accuracy.

Fig. 1. 1) Image of the driving element scale graduations; 2) image of the driven element scale graduations; 3) image of the combined graduation of the driving and driven elements.

Fig. 2. 1) Image of the driving element scale graduations; 2) image of the driven element scale graduations.

The essence of the method consists in observing the coordinated displacement of the driving and the driven control mechanism elements which are interconnected during operation by appropriate scales. The optical images of the scales are made to coincide in the field of vision of a double microscope.

Fig. 3

Fig. 4

Moreover, the graduations of the scales are chosen in such a manner that the displacement of the driving element by one division causes a displacement of the driven element also by one division. In other words, the relation of the graduations of the driving and driven elements of the control mechanism is equal to their gear ratio, i.e.

$$i = \frac{a_1}{a_2} = \frac{V_1}{V_2},$$ (1)

where a_1 and a_2 are the distances between the graduations of the driving and driven element scales, respectively; V_1 and V_2 are the velocities of the driving and driven elements, respectively.

In order to combine the images of two adjacent graduations of the driving element scale with two adjacent graduations of the driven element in one field of vision of a double microscope (Fig. 1), the following equality should hold

$$A = a_1 V_1^{\times} = a_2 V_2^{\times},$$ (2)

where $a_1 V_1^{\times}$ is the distance between optical images of two adjacent graduations of the driving element scale as seen in the field of vision of the double microscope eyepiece; $a_2 V_2^{\times}$ — distance between the optical images of two adjacent graduations of the driven element scale as seen in the field of vision of the double microscope eyepiece; $V_1^{\times}$ — magnification of the microscope's optical branch which reproduces the driving element scale; $V_2^{\times}$ — magnification of the microscope's optical branch which reproduces the driven element scale.

It follows from (2) that (1) will be applicable in the field of vision of the double microscope if the magnification of its objectives is inversely proportional to the gear ratio of the controlled mechanism, i.e.,

$$\frac{V_1^{\times}}{V_2^{\times}} = \frac{a_2}{a_1} = \frac{1}{i} = i'.$$ (3)

When the graduation images of the driving and driven elements are made to coincide optically (or are placed in line) in the field of vision of the double optical microscope, one will see the picture shown on the right of Fig. 1, if the equalities (1)-(3) are preserved. These equalities hold, in the absence of a kinematic error in the mechanism under control, since the movement of the driving and driven elements, and hence of the scales connected to them, is synchronized. Moreover the relative position of the graduations will remain constant in the field of vision of the double microscope along the entire length of the scale, as long as the actual law of movement of the driven element corresponds to the required law of movement.

If there is a kinematic error the actual law of movement will differ from the required law. In this case, Eqs. (1)-(3) will no longer hold and the graduations' movement will no longer be synchronized. The relative position of the graduations will continuously change in the field of vision of the microscope: the graduations of the driven element will either lead or lag behind the graduations of the driving element (Fig. 2). The value of the variations in the relative position of the graduations is proportional to the kinematic error of the controlled mechanism and is counted in the direction of the graduations' movement.

In order to increase the accuracy of estimating the kinematic error, the image of one of the graduations is turned with respect to the other by means of the optical system, thus making the graduations cross at an angle γ (Fig. 3).

The crossing point of the graduations will be displaced along a straight line through the middle of the microscope's field of vision in the direction of the graduations' movement, if there is no kinematic error.

If there is a kinematic error in the controlled mechanism, the crossing point will be displaced according to the value and sign of the error to the left or the right of the middle line (Fig. 4). The value of this displacement will be equal to $\cot \gamma$ times the value of the error counted in the direction of the graduation images' movement, i.e.,

$$\Delta_2 l = \Delta_1 l \cot \gamma. \tag{4}$$

where $\Delta_2 l$ is the value of the graduations images' crossing point displacement from the middle line; $\Delta_1 l$ is the value of the error of reading in the direction of the graduation images' movement; γ is the angle between the graduation images.

The value of the displacement can be read off the scale drawn on the eyepiece plate of the double microscope.

It should be noted that a turn in the graduations of either the driving or driven element requires a correction of magnification of one of the microscope objectives or the spacing of the graduations of one of the two scales. In fact, according to Fig. 3, when the graduations of one of the scales are turned, for instance, those of the driving element, the equalities (1) and (2) no longer hold, since in this instance

$$A_1 > A_2 \tag{5}$$

where

$$A_1 = a_1 V_1^\times \quad \& \quad A_2 = a_2 V_2^\times$$

and

$$A_2 = A_1 \cos \gamma. \tag{6}$$

Hence in calibrating the scales of the driving and driven elements, and selecting magnifications of the double microscope objectives, the following equality must be preserved

$$\frac{a_2 V_2^\times}{a_1 V_1^\times} = \cos \gamma. \tag{7}$$

The total transfer ratio of the instrument including the effect of the angle between the graduation images will be

$$K = V_2^\times \cot \gamma V_0^\times. \tag{8}$$

where $V_2^\times$ is the magnification of the driven scale objective; γ is the angle between the graduation images; $V_0^\times$ the magnification of the eyepiece.

Here the transfer ratio of the instrument is taken to be the ratio of the displacement of the graduation images' crossing point $\Delta_2 l$ from the middle line of the microscopic eyepiece plate to the actual value of the kinematic error δl which produced this displacement, i.e.,

$$K = \frac{\Delta_2 l}{\delta l}. \tag{9}$$

Thus, for instance, with an objective magnification of 20×, an angle between the two graduation images of 11°45' and an eyepiece magnification of 10 we obtain

$$K = 20 \cdot 5 \cdot 10 = 1000.$$

By means of the above method it is possible to check the kinematic accuracy of various mechanisms in which it is required to determine the value of the discrepancy between two given movements: for instance, two forward motions, a forward and a rotary motion, or two rotary motions.

In checking the discrepancy of two forward movements (control of a linear transfer ratio) the elements which are being controlled are connected to linear scales. It is thus possible to check by this method kinematic relations with any transfer ratios, including irrational numbers. In the latter case it is necessary to ensure an irrational relation between the spacings of the two scale graduations.

When checking the discrepancy between a forward and rotary movement (control of thread parameters), a linear scale is connected to the element with the forward motion and a circular scale to the element with the rotary motion.

In this instance, the relation of the spacing between graduations of the linear scale a_2 to angle ψ subtended by two adjacent graduations of the circular scale, must be equal to the parameter of the helical movement P, i.e.

$$P = \frac{V}{\omega} = \frac{a_2}{\psi}, \tag{10}$$

where V is the velocity of the forward movement of the driven element; ω is the angular velocity of the driving element.

Hence

$$a_2 = P\psi. \tag{11}$$

When the image of the linear scale graduations is inclined at an angle γ we have, according to (7):

$$a_1 = \frac{V_2^\times}{V_1^\times \cos \gamma} a_2, \tag{12}$$

where $V_2^\times$ is the magnification of the linear scale double microscope objective; $V_1^\times$ — ditto for the circular scale; a_1 is the length of the arc measured between two adjacent graduations of the circular scale.

But

$$a_1 = R\psi \tag{13}$$

where R is the radius of the circular scale.

Hence

$$\frac{V_2^\times}{V_1^\times} \cdot \frac{P}{R} = \cos \gamma; \tag{14}$$

$$\frac{V_2^\times}{V_1^\times} = \frac{R}{P} \cos \gamma. \tag{15}$$

In order to obtain a whole number $\underline{n}$ of the circular scale graduations the following equality must hold:

$$n = 2\pi/\psi = \text{whole number.}$$

When checking the discrepancy between two rotary movements (control of an angular transfer ratio) both elements are connected to circular scales.

The relation of the angles ψ_1 and ψ_2 subtended by two adjacent pairs of graduations of the circular scales must be equal the transfer ratio

$$\frac{\psi_1}{\psi_2}=i, \tag{16}$$

where ψ_1 is the angle subtended by two adjacent graduations of the driving element scale; ψ_2 — ditto for the driven element.

Since the circular scales are closed, the number of their graduations must be equal to an integer:

$$2\pi/\psi_1 = \underline{m} \text{ is an integer}, \qquad 2\pi/\psi_2 = \underline{n} \text{ is an integer}$$

hence

$$i=\frac{\psi_1}{\psi_2} = \frac{m}{n}. \tag{17}$$

i.e., it is only possible to check drives which have rational transfer ratios expressed by an irreducible fraction.

If one of the elements, however, has a scale which does not complete the circle, its circuit is not closed. Under this condition it is possible to control drives with any transfer ratio.

The magnifications of the microscope branches must satisfy the equation

$$\frac{V_2^\times}{V_1^\times} = \frac{a_1}{a_2} = \frac{R_1 \psi_1}{R_2 \psi_2} = \frac{R_1}{R_2} i, \tag{18}$$

where R_1 and R_2 are the circular scale radii of the driving and driven elements, respectively.

Taking into consideration the angle of slope of one of the scales, for instance the driven scale, we obtain

$$\frac{V_2^\times}{V_1^\times} = \frac{a_1}{a_2} \cos\gamma = \frac{R_1 \psi_1}{R_2 \psi_2} \cos\gamma = \frac{R_1}{R_2} i \cos\gamma \tag{19}$$

or

$$\frac{V_2^\times}{V_1^\times} \cdot \frac{1}{\cos\gamma} = \frac{a_1}{a_2} = \frac{R_1 \psi_1}{R_2 \psi_2} = \frac{R_1}{R_2} i. \tag{20}$$

Regarding the directions of movement and position of the axis of rotation of the elements, this method does not stipulate any limitations, since the optical system provides the means to transfer the image of the graduations to any required place and turn it to any angle. The optimum value of angle γ is in the range of $5° \leq \gamma \leq 15°$. In this case, $\cos\gamma$ is close to 1 and the difference between A_1 and A_2 can be corrected when the magnifications $V_1^\times$ and $V_2^\times$ of the instrument are adjusted.

CONCLUSIONS

This method can be used for checking the kinematic accuracy of various mechanisms such as kinematic pairs, metal-working lathes, screws, worm gears, and other devices.

This optical method of nonprototype checking of the kinematic accuracy was used in practice in checking the accuracy of the chain feed of a gear-hobbing machine [1], which was constructed to the design of the author of this article by the gear transmission section of TsNIITMASh. The tests showed that the instrument can be recommended for use in industry.

A model of an instrument for checking the accuracy of screws was constructed under the author's guidance in the Moscow Engineering Evening Institute in conjunction with the Interchangeability Bureau of the Committee of Standards, Measures, and Measuring Instruments. Since the model was tested and certain modifications made, a second model is being constructed which can also be recommended for general use.

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DETERMINATION OF SAGGING IN BUILDING CONSTRUCTIONS
IN FIELD AND FACTORY TESTING

I. L. Zhodzishskii and V. G. Zolotukhin

Numerous reinforced concrete prefabricating plants have come into operation in the Soviet Union in recent years; these plants test daily the bending resistance of experimental or test samples of slabs, beams, girders, and other bending structures. In these tests vertical displacements (sinking) are measured with an accuracy of 0.1 mm in several places, and from their differences the sagging is determined, which increases with load and the duration of its application.

Fig. 1

Fig. 2

In research laboratories, vertical displacements $\delta \geq 10$ mm are measured by means of deflectometers which are placed for the entire duration of testing at every required point.

Under production conditions it is, as a rule, impossible to use deflectometers, since during testing, especially prolonged testing, the instrument fixtures may be displaced and the instruments themselves damaged.

The authors of this article use, in factory and field tests, an instrument they have constructed for measuring vertical displacements.

The instrument (Fig. 1) consists of rod 1 and micrometer head 2, made out of a conventional micrometer with half its frame cut off. The upper part of the rod has a slot for a locating pin, 3. The bottom of rod 1 is screwed to an extension piece 4 which has at its lower end a cone-shaped recess at an angle of 100-110°. The instrument set contains several extension pieces of different lengths.

The instrument is placed in turn at several points only for the time it is necessary to measure, i.e., for 0.5-1 minute.

Metal pins (markers) 5 are fixed to the construction under test on approximately the same level at the points whose sagging is being determined, and under them guide fingers 3 are secured. Bearings 6, consisting of a plate with a conical pin, are fixed to the floor by cement or plaster of Paris.

The instrument is supplied with extension pieces 4, of a length suitable for the height of markers 5 above ground level, so that for the initial measurements the micrometer head is near its top limit. The alignment of the axes of marker 5, and micrometer head 2, is attained by the original adjustment of the support which moves on a thread along the axis of guide finger 3.

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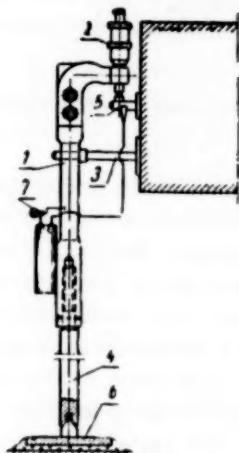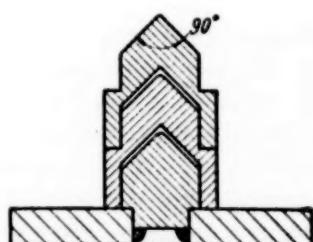
* See English translation.

Since the range of the micrometer is only 25 mm and the sagging of the test points of the measured construction often reaches 50-70 mm, the footstep bearing is extended by several end links with an effective height of 15 mm (Fig. 2). In the course of testing the end links are removed as required. Immediately before and after removing a link, measurements are taken without changing the load.

It is advisable to fix markers 5 on the top face of the construction under test 10-30 mm from the edge. It is not always possible, however, to do it, and the marking device consisting of a finger with a marker has to be fixed on the side face of the construction by hammering the finger into the porous concrete (the pointed finger can be easily hammered into and will hold firmly in porous concrete γ = 600-1200 kg/ m³) or by fixing to the face by means of alabaster a plate with the finger welded to it. In order to avoid false readings due to the bending or turning of the finger, it is convenient to use an electrical signalling system, whose circuit is shown in Fig. 1; it was found in practice that the signalling lamp 7 lights before the micrometer clicking device operates.

DEVICE FOR POLISHING WORKING SURFACES OF MICROMETERS
MEASURING OVER 100 mm

G. I. Kholod and V. M. Shitikov

The majority of 100 mm micrometers are made with pressed-in anvils. Hence for lapping the measuring surfaces it is necessary to press the anvil out of its seating and then put it back again after lapping, thus upsetting the parallelism of the measuring surfaces. The attachment used by us provides for lapping without pressing out the anvil; thus, the parallelism of the measuring surfaces is not disturbed and the time taken by the operation greatly decreased.

The attachment is made out of a 25-50 mm micrometer whose anvil is replaced by a hole with a locking device.
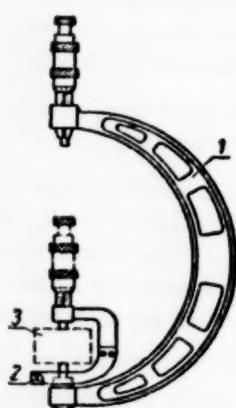
The attachment (see figure) is placed on the anvil of the micrometer frame 1, fixed to it by means of clamping screw 2. The microscrew is taken out of the micrometer under repair and screwed into the attachment; then a cast iron lap 3 is placed between the anvil and the microscrew and the surfaces lapped with a rotary to-and-fro movement. In order to obtain mirror surfaces the lapping can be done with two sets of laps of 4 pieces each, with a difference in height between them of 0.125 mm. One set serves for lapping with rough paste and the other for fine paste. This speeds up the lapping, since it is not necessary to clean the laps after changing pastes. The rough, medium, and fine GOI paste is used for lapping. When the surfaces are very worn, deeply scratched, or corroded, oxide of boron carbide is used, followed by paste.

DIVIDING HEAD WITH A SINE RULE

A. B. Frankel'

A dividing head of original construction (designed by Comr.Privalov) has been developed at the ZIL plant. The head (see figure) consists of a dividing disk, 1, and a special sine rule, 2, mounted on a mandrel fixed between two pointed journals of head stocks 3 and 4.
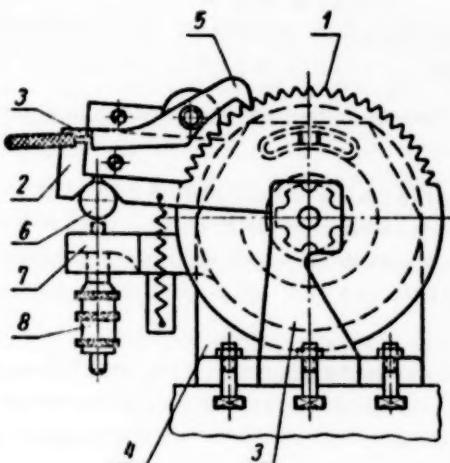
A dividing disk, 1, is mounted at one end of the mandrel; the other end serves to hold the machined or measured article. The dividing disk, 1, is placed near the front head stock, 3. The angle of its rotation about the axis of the front headstock pivot is set by means of locator 5, which is mounted on the body of the special sine rule, 2; the front headstock, 3, pivot serves as one of the measuring rollers of the rule, the other roller, 6, is fixed in the same way as in a standard sine rule. The base of the rule consists of the 150 mm distance between the axis of roller, 6, and that of the headstock pivot.

Multiples of 5° are measured along the dividing disk which has 72 dividing teeth, and the angles in the intervals between the teeth are measured on the sine rule.

The angle of rotation of the sine rule 2 frame about the headstock pivot is determined by the distance between the surface of roller 6, and table 7, which is rigidly fixed to the front headstock frame. The surface of table, 7, is lower than the pivot, 1, axis by an amount equal to the radius of roller, 6.

This distance can be measured by a block gage placed between roller, 6, and table, 7, or by means of the fixed micrometer head, 8, in such a manner that for the zero reading the end of the micrometer spindle is below the pivot axis level by an amount equal to the radius of roller 6.

Thus, by means of the dividing disk it is possible to rotate the article through angles which are multiples of 5° and in addition turn the dividing disk by means of the sine rule through any angle within the 5°.

REPAIRS OF LEVER MICROMETERS

A. V. Ervais

Lever-type micrometers made to GOST 4381-48 are a combination of a normal spindle micrometer with a lever mechanism mounted in its hollow frame. The moving anvil 1 (see figure) is loaded by spring, 2, and ensures a constant measuring effort. Pin, 3, screwed into the anvil stops it from turning. The spherical end of the pin engages in guide groove, 4. The small adjustable arm of lever, 5, engages with a notch in the anvil. By this means, errors in other transmission links can be corrected. The large arm, 6, of the lever has a geared quadrant, 7, which engages with a pinion. Axle, 8, of the pinion has pointer, 9, attached to it. The backlash of the pinion and geared quadrant is removed by hairspring 10. The end position of the lever is set by the adjustable end stop. 11. All the components of the lever mechanism are mounted on plate, 12, which after assembly is fixed in its position in the micrometer frame.

The withdrawal of the anvil (detaining) is accomplished by push button 13, which presses against lever 14. The end of this lever engages with the notch of anvil 1. The return of the push button and the lever is ensured by means of flat spring 15.
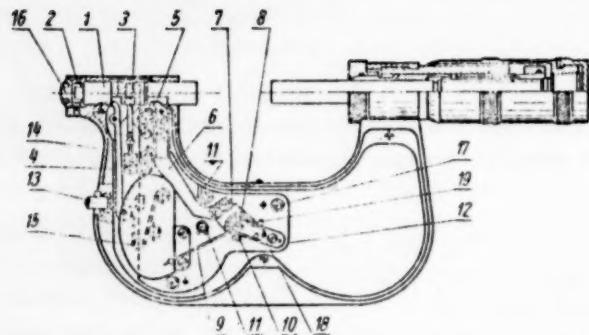
The technical characteristics of lever micrometers are: calibrated in steps of 2 μ; distance between graduations 1.32 mm; gear ratio 663; range ± 0.02 (0.04) mm; permissible error of readings: for the micrometer screw ± 0.003 mm, and for the lever mechanism ± 1 μ; the error of the kinematic system is 2 μ; measuring effort 200-400 g-wt; permissible variations of the measuring effort 100 g-wt.

The set of tools of the lever-type micrometer includes a cylindrical gage and a key for setting the end stop to a given tolerance on the scale.

The repairs of the lever-type micrometers are divided into two parts: the repairs of the micrometer screw unit and that of the lever mechanism.

The repairs of the micrometer screw unit are carried out by the means and methods described in [1]. It should be noted that if the polishing of the measuring surfaces is done while the micrometer is held in one's hand, the lap should be gripped between the anvil and the spindle with a pressure at which the lever mechanism pointer is deflected to the extreme right. If, however, the micrometer is held in a vise, the pointer should be in the zero position.

For the repairs of the lever mechanism, basic spare parts are required, such as the anvil, pin, levers, fork, quadrant, pinion, pointer, pointer socket, dog axle, and hairspring. Available spare parts speed up repairs considerably and improve their quality. It is permissible to use parts of micrometers which have been scrapped as faulty.

Elimination of Defects in the Anvil. In the first place, the interaction of the lever mechanism parts is checked. For this purpose the measuring surfaces of the spindle and the anvil are brought into contact and the movement of the anvil is observed while the microscrew is being slowly screwed up and unscrewed (within the limits of the lever mechanism movement). The movement of the anvil should be easy and smooth.

Next radial play is checked. Radial pressure is applied to the anvil by means of one's fingers and the reading of the pointer observed.

Its variations should not exceed 0.001 mm.

At the same time, the anvil is turned by means of one's fingers clockwise and anticlockwise to check circular play. The reading deviations in this case should not exceed 0.001 mm.

In both instances, the pointer should return to zero when the pressure is released.

Sticking or a slow return of the anvil to normal points to dirt or corrosion of its surface or of the opening in which it operates. The penetration of cutting emulsion, when the micrometer is used for measurements at the lathe, may also cause sticking. Cleaning and a little watch oil applied to the anvil and its opening will eliminate this effect.

Radial rocking of the anvil (radial free play) is due to the wearing of the anvil and its opening. This defect can be rectified by thick chromium plating of the anvil and its subsequent lapping to the hole, or by replacing the anvil by a new one. As a temporary measure the defect can be rectified by pressing in the edges of the anvil hole. For this purpose the anvil and the mechanism are taken out of the frame, a ball 10-12 mm diam is placed on the edge of the hole and lightly tapped with a hammer through a copper pad. After this operation the anvil is slightly lapped without any abrasive until it moves smoothly in the hole without radial free play.

The swinging of the anvil about its axis (circular free play) occurs when pin, 3, or its guiding groove, 4, are loosely fixed or worn. In the first place it is necessary to check the fixing of the pin and guide and then adjust the guide so as to reduce the width of the groove. It is also possible to rotate the pin a little, turning the unworn part to the groove, by placing a packing washer under the thread. After assembly, the movement of the anvil should be smooth and without swinging.

The axial free play of the anvil (backlash) can be discovered by hand or by means of the microscrew placed in contact with the anvil. An axial free play exceeding 0.5 μ is not permissible. Backlash can be due to insufficient tension in spring 2, or a gap between small lever 5 and the anvil.

The defect is rectified by adjusting the spring (by stretching it out or pressing it in with cap, 16), or by exchanging it for a new one. If the defect cannot be eliminated in this manner, it means that lever, 5, is not touching the anvil. In such a case, the three screws, 17, should be loosened and plate, 12, slightly turned with respect to the anvil.

When the anvil is moved along its axis the pointer should deflect smoothly and return to its initial position.

Displacement of the pointer under its own weight occurs when lever, 6, is loose or there is considerable free play between geared quadrant, 7, and the pinion. Free play in lever, 6, can be checked by slightly pressing its axle and noting at the same time the position of the pointer on the scale. The cover which conceals the mechanism should be removed beforehand. In its resting position the pointer should be in the left hand side (minus) end of the scale and must not move under its own weight when the instrument is tipped. With a slight pressure on the axis, the pointer should not deflect by more than five graduations and must return to the initial position after the load is removed.

In order to avoid the rocking of the lever, it should be taken out of the micrometer and the axle hole slightly decreased in size.

This is done by pressing in the surface of the lever around the hole by a punch lightly tapped with a hammer. Next the hole is carefully reamed out to the size of the axle. When replaced in position, lever 6 complete with the quadrant should move easily under its own weight (even if the plate is at an angle of approximately 45°) and must not rock.

The backlash between the geared quadrant, 7, the pinion and axle, 8, is taken up by means of hairspring, 10, and pointer 9 is fixed along the longitudinal axis $O-O_1$ of bridge, 18; moreover, the end of the hairspring must be on the same axis. If this is not the case, the hairspring is adjusted by means of tweezers. When the correct position of the hairspring is attained, it is fixed in its socket with wedge, 19.

An increase in the hairspring pressure can also be achieved by turning the pinion. For this purpose one of the end-stop screws is taken out, the quadrant is swung beyond its point of engagement with the pinion, which is then rotated and again engaged with the quadrant and the end-stop screw returned to its normal position.

The gap between the pointer and the scale should be between 0.5-0.7 mm. The correct position of the pointer is attained by adjusting it with tweezers.

When the detainer is operated, the pointer should be deflected to the right of the scale and then return to its initial position. The range of the pointer movement is adjusted by means of two end-stops 11, which limit the movement of lever, 6.

Instability of readings in any part of the scale must not exceed 0.5 μ. This is checked by means of a rapid and slow operation of the detainer in three positions of the pointer: in the middle of the scale and three divisions from each end.

Instability can be due to insufficient hairspring pressure (play between the quadrant and the pinion), loose fixing of the contact ball in the small lever, 6, dirt or oil between the ball and the contact surface of the anvil, or radial play in the anvil. In the first place, the contact surfaces of the lever and the anvil are washed out, the ball is tightened in its position by means of a punch, or the radial play of the anvil is eliminated in the manner described above.

Instability of readings can also be caused by play in the pinion axis, 8. This is eliminated by the flat spring whose adjustment takes up the play in the axle.

The measurement effort of the micrometer is measured on a dial spring scale and must be within the limits of 200-400 g-wt. The measuring effort is adjusted by means of spring 2 and cap 16. After adjustment it should be ascertained that there is no free play in the anvil.

Error of readings of the lever mechanism is caused by radial or circular play and backlash of the anvil, wear of the measuring surfaces of the spindle or anvil, or the misadjustment of the mechanism's gear ratio. The first

two defects are rectified in the manner already described, the third by lapping the measuring surfaces. An incorrect gear ratio is rectified by displacing the small lever, 5, with respect to the large one, 6, first loosening slightly two screws. After adjustment the two screws are firmly tightened again and the error of readings rechecked.

The amount by which the lever should be displaced can be arrived at from the following calculation.

The gear ratio is:

$$K = \frac{b}{i},$$

where $\underline{b}$ is the distance between graduations; $\underline{i}$ is the value assigned to a graduation.

For $b = 1.32$ mm and $i = 0.002$ mm, $K = 1.32/0.002 = 660$.

Value $\underline{a}$ of the adjustable arm is determined from the formula

$$a = \frac{R}{r} \cdot \frac{L}{K},$$

where R = the radius of the geared quadrant; $\underline{r}$ is the radius of the pinion equal to 1.225 mm; L is the length of the pointer.

Substituting the known quantities we obtain:

$$a = \frac{35.5}{1.225} \cdot \frac{84}{660} = 3.69 \text{ mm}.$$

If it is found in checking that the reading is smaller than the nominal value (for instance 0.0015 instead of 0.002 mm) then:

$$K = \frac{1.32}{0.0015} = 880.$$

In this case the value of the small arm $\underline{a}$ will amount to 2.77 mm. The value of the displacement $S = a - a_1 = 3.69 - 2.77 = 0.92$ mm, i.e., the small arm, 5, must be extended by 0.92 mm (decreasing the gear ratio K).

Sometimes errors of reading are caused by the wear of the quadrant or the pinion and produce a variable error at different parts of the scale. It is often possible to rectify the error by changing the position of the pinion with respect to the quadrant. For this purpose the pinion is disconnected from the quadrant in the manner described above, turned with respect to the latter by one tooth and the reading rechecked. This operation is repeated until the required accuracy is attained. If by this means the error cannot be rectified, the pinion must be changed.

These methods of repairing a lever micrometer can also be used for repairing a lever gage of Soviet make by GOST 4731-49, since their mechanisms are identical.

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[1] A. V. Érvais, Izmeritel'naya Tekhnika No. 5 (1959).*

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* See English translation.

HARDNESS CRITERION IN DESIGNING LEVERS FOR WEIGHING EQUIPMENT

M. Ratsiu

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Let us examine the operation of a balance lever (Fig. 1) with load S which is being measured and balancing load G at distances $\underline{s}$ and $\underline{g}$, respectively, from the fulcrum. Under load the lever arms are strained, and the position of the load knife-edge bearings with respect to the fulcrum bearings is changed. Since the knife-edges of the bearings are a certain distance $\underline{i}$ away from the neutral line of the lever, a turn in the cross sections of the latter produces increments in Δs and Δg.

Fig. 1

Fig. 2
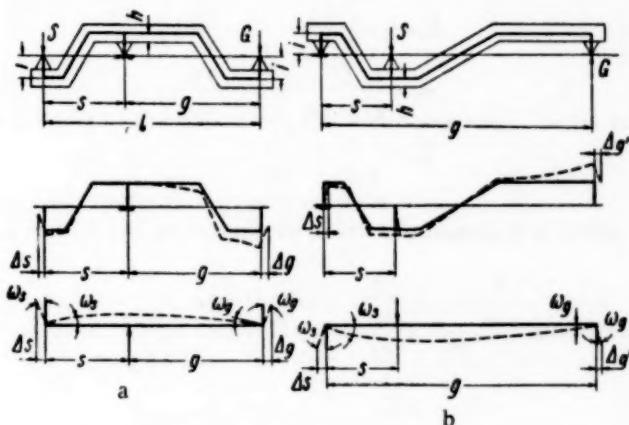
The vertical displacements of the bearings which produce variations in sensitivity, stability, and the period of oscillations are especially interesting when studying laboratory balances. In the case of commercial balances the requirements of the above parameters are not so strict and the effect of vertical displacements can be neglected.

The variations of the length of arms produces systematic errors which are a function of the load.

The object of the present work is to derive substantial stiffness of the levers criteria which would provide systematic errors within permissible limits.

In order to simplify this study, let us consider the lever as a beam with a linear axis freely suspended at the ends from two rigid supports (see the bottom drawing in Figs. 1,a and 1,b). The ratio of the lever arms, one loaded with a unit load S = 1 and the other with the balancing load $g = 1\frac{s}{g}$ is:
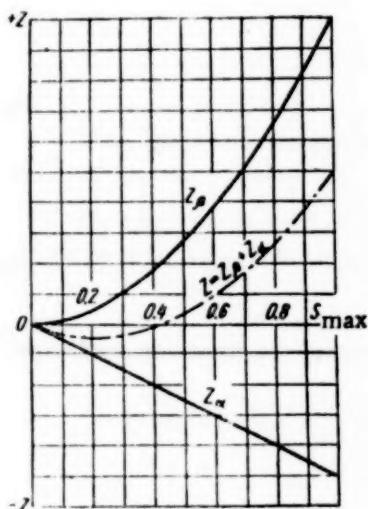
$$\frac{g+\Delta g}{s+\Delta s}$$

The increment Δs of the measuring arm is partly compensated by the increment Δg of the balancing arm. Including this compensation we have:

$$\frac{g+\Delta g-\dfrac{g}{s}\Delta s}{s}=\frac{g}{s}\left(1+\frac{\Delta g}{g}-\frac{\Delta s}{s}\right)=\frac{g}{s}(1+\beta)$$

where $\beta=\Delta g/g-\Delta s/s$ is the bending error coefficient.

The expression for β remains the same both for a lever of the 1st (Fig. 1,a) and the 2nd order (Fig. 1,b).

It will be seen from Fig. 1 that

$$\Delta s=i\,\sin\,\omega_s;\;\Delta g=i\,\sin\,\omega_g$$

where i is taken to be the same for all the knife edge bearings of a lever.

When a lever system balance is studied, it is possible to represent the effect of the incremental lengths of all the levers by bending coefficient $\bar{\beta}_n$ referred to a unit load at the first (load carrying) lever:

$$\bar{\beta}_1=\beta_1=\left(\frac{\Delta g_1}{g_1}-\frac{\Delta s_1}{s_1}\right);$$
$$\bar{\beta}_2=\frac{s_1}{g_1}\left(\frac{\Delta g_2}{g_2}-\frac{\Delta s_2}{s_2}\right);$$
$$\bar{\beta}_3=\frac{s_1 s_2}{g_1 g_2}\left(\frac{\Delta g_3}{g_3}-\frac{\Delta s_3}{s_3}\right)\;\;\text{etc.}$$

For the system as a whole it is possible to write, by neglecting the factors $\bar{\beta}_n$:

$$\frac{g_1}{s_1}(1+\bar{\beta}_1)\frac{g_2}{s_2}(1+\bar{\beta}_2)\frac{g_3}{s_3}(1+\bar{\beta}_3)\;\cdot\;\cdot\;\cdot\;=\tag{1}$$
$$=\frac{g_1}{s_1}\cdot\frac{g_2}{s_2}\cdot\frac{g_3}{s_3}\cdot\ldots\cdot(1+\bar{\beta}\text{ gen}).$$

where $\bar{\beta}_{gen}=\Sigma\bar{\beta}_n$.

Notation $\bar{\beta}_{gen}$ permits one to consider problems involving an entire lever system as one lever.

Owing to the variations of the lever arms the initial balance equation:

$$S+S_0=(G+G_0)\frac{g}{s}-\frac{M}{s}\tag{2}$$

takes the form

$$S+S_0=(G+G_0)\frac{g}{s}[1+\beta(S+S_0)]-\frac{M}{s}\tag{3}$$

Here S_0 and G_0 are the tare loads applied to the knife edge bearings of the measuring and balancing arms, respectively; M is the moment of the force of gravity on the lever.

Considering that

$$\beta(G+G_0)\frac{g}{s}\simeq\beta(S+S_0),$$

let us rewrite (3) in the form

$$(S+S_0)=(G+G_0)\frac{g}{s} - \frac{M}{s} + \beta(S+S_0)^2. \qquad (3\,a)$$

For $S = 0$ Equation (3 a) takes the form:

$$S_0 = G_0\frac{g}{s} - \frac{M}{s} + \beta S_0^2 . \qquad (3\,b)$$

Subtracting (3 b) from (3 a) we have

$$S=G\frac{g}{s} + \beta S(2S_0+S)=G\,\frac{g}{s}+Z_\beta \quad .$$

where $Z_\beta = \beta S(2S_0 + S)$ denotes the error of the balance due to the bending of the levers.

By similar reasoning we obtain an expression for the error of a system of levers:

$$Z_{gen} = \bar{\beta}_{gen}(2S_0+S). \qquad (4)$$

In order to compensate for the error due to bending of the levers the ratio of the arms is altered in such a manner that the value of the compensation becomes proportional to the load

$$Z_a = aS. \qquad (5)$$

where Z_α is the change in the reading of the balance due to compensation; α is the coefficient equal to Z_α for $S = 1$.

For a system of levers we shall obtain as we obtained for β

$$Z_a = S\Sigma\bar{a_1}=S\bar{a}_{gen}$$

Taking into consideration the effect of compensating the total error Z_{gen} is represented for one lever by:

$$Z_{gen}=Z_\beta +Z_a =S(a+2\beta S_0+\beta S); \qquad (6)$$

for a system of levers by:

$$Z_{gen}= S(\bar{a}_{gen}+2\bar{\beta}_{gen}S_0+\bar{\beta}_{gen}S). \qquad (6\,a)$$

If Z_α has a reversed sign to Z_β a partial compensation of the error due to the bending of the levers occurs, as it will be seen from Fig. 2.

For many common types of balances the permissible error is specified in the following manner (Fig. 3). In the range from S_{max} to $0.2\,S_{max}$ the permissible error F is proportional to the load:

$$F = cS.$$

For loads smaller than $0.2\,S_{max}$ the permissible error is constant and equal to $F = \frac{c}{5}\,S_{max}$.

Assuming the conditions that:

$$|Z_{gen}| < +cS_{max} \quad \text{for} \quad S=S_{max};$$
$$|Z_{gen}| < -\frac{c}{5}S_{max} \quad \text{for} \quad S=0.2\,S_{max}$$

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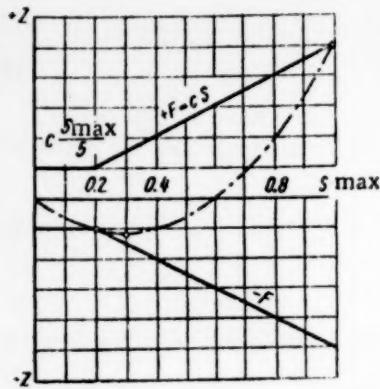
Fig. 3

and using Eq. (6 a) we obtain two simultaneous equations whose solutions provide the limiting values of $\bar{\alpha}_{gen}$ and $\bar{\beta}_{gen}$:

$$\bar{\beta}_{gen}=2.5\frac{c}{S_{max}} \qquad (7)$$

$$\bar{\alpha}_{gen}=-c\left(1.5+\frac{5S_o}{S_{max}}\right). \qquad (8)$$

An analysis of expression (6 a) shows that function Z_{gen} has a minimum for $S = 0.3 S_{max}$. The value of Z at this point with limiting values of $\bar{\alpha}_{gen}$ and $\bar{\beta}_{gen}$ is

$$Z_{gen}=-0.225cS_{max} < F = 0.3cS_{max}.$$

Thus the limiting value of $\bar{\alpha}_{gen}$ and $\bar{\beta}_{gen}$ from Eqs. (7) and (8) provide from the inflection of Z_{gen} a shape of the error curve which does not exceed the limits of the permissible error F over the whole range of loads S.

Considering that $\bar{\alpha}_{gen} = \Sigma\bar{\alpha}_n$ and $\bar{\beta}_{gen} = \Sigma\bar{\beta}_n$ the limiting values of $\bar{\alpha}_n$ and $\bar{\beta}_n$ for individual levers should be specified; considerations of equal strength lead to recommending equal variations of transfer ratios when the levers are strained:

$$\frac{\Delta g_1}{g_1} - \frac{\Delta s_1}{s_1} = \left(\frac{\Delta g_2}{g_2} - \frac{\Delta s_2}{s_2}\right) \cdots = \left(\frac{\Delta g_n}{g_n} - \frac{\Delta s_n}{s_n}\right).$$

then

$$\bar{\beta}_{gen}=\Sigma\bar{\beta}_n=\beta\left(1+\frac{s_1}{g_1} + \frac{s_1 s_2}{g_1 g_2} + \cdots\right).$$

For this case Eq. (7) can be written as

$$\beta_{lim}=2.5\frac{c}{S_{max}} \cdot \frac{1}{1+\dfrac{s_1}{g_1} + \dfrac{s_1 s_2}{g_1 g_2} + \cdots}. \qquad (9)$$

Using Eqs. (7) or (9) for calculating the lever cross section for which a compensation of the error is possible, the permissible overloading of the balance as stipulated in the specification should be remembered with the value $S_{ovl} = mS_{max}$, where $\underline{m}$ is the coefficient of the permissible overloading, usually taken as 1.3, should be taken into consideration.

Considering the lever as a beam with a linear axis resting at its ends on rigid supports, and assuming in view of the small values of ω_i that $\sin\omega_i = \tan\omega_i$, we obtain

for levers of the first order:

$$\sin\omega_s=\text{tg}\,\omega_s =\frac{1}{S} \cdot \frac{M_{bnd}}{6EJ}(2g+s);$$

$$\sin\omega_g=\text{tg}\,\omega_g=\frac{1}{S} \cdot \frac{M_{bnd}}{6EJ}(g+2s);$$

for levers of second order:

$$\sin\omega_s=\text{tg}\,\omega_s=\frac{1}{S} \cdot \frac{M_{bnd}}{6EJ}(2g-s);$$

$$\sin\omega_g=\text{tg}\,\omega_g=\frac{1}{S} \cdot \frac{M_{bnd}}{6EJ}(g+s),$$

$$(10)$$

where M_{bnd} is bending moment acting on the lever; E is the modulus of elasticity; J is the moment of inertia of the lever cross section.

From Eq. (10) we obtain formulas for β in the case of a lever of the 1st order

$$\beta = \frac{1}{S} \, i \left(\frac{tg\omega_g}{g} - \frac{tg\omega_s}{s} \right) =$$

$$= \frac{1}{S} \cdot \frac{M_{bnd}}{3EJ} \, i \left(\frac{g}{s} - \frac{s}{g} \right) ; \tag{11}$$

and in the case of a lever of the 2nd order

$$\beta = \frac{1}{S} \, i \left(\frac{tg\omega_g + tg\omega_s}{g} - \frac{tg\omega_s}{s} \right) =$$

$$= \frac{1}{S} \cdot \frac{M_{bnd}}{3EJ} \, i \left(\frac{g}{s} - 2 \right) . \tag{12}$$

It follows from (11) and (12) that the error due to bending of the levers becomes zero when $s = g$ for levers of the first order (equal arms balance) and when $g/s = 2$ for levers of the second order.

For a maximum load we have for a lever of the 1st order

$$\beta = \frac{1}{S_{max}} \cdot \frac{M_{bnd \cdot max}}{3EJ} \, l \left(\frac{g}{s} - \frac{s}{g} \right) =$$

$$= \frac{1}{S_{max}} \cdot \frac{\sigma}{3E} \cdot \frac{l}{h} \left(\frac{g}{s} - \frac{s}{g} \right) ; \tag{11 a}$$

and in the case of a lever of the 2nd order

$$\beta = \frac{1}{S_{max}} \cdot \frac{M_{bnd \cdot max}}{3EJ} \, l \left(\frac{g}{s} - 2 \right) =$$

$$= \frac{1}{S_{max}} \cdot \frac{\sigma}{3E} \cdot \frac{i}{h} \left(\frac{g}{s} - 2 \right) . \tag{12 a}$$

where $\sigma = \dfrac{M_{bnd \cdot max}}{J} \, h$ is the tension in the lever; $\underline{h}$ is the distance form the neutral axis (see Fig. 1).

Taking the limiting values of β as expressed in Eq. (7) and (9) we have for a lever of the first order

$$\beta = 2.5 \frac{c}{S_{max}} = \frac{1}{S_{max}} \cdot \frac{\sigma}{3E} \cdot \frac{i}{h} \left(\frac{g}{s} - \frac{s}{g} \right) . \tag{13}$$

where

$$\sigma = 7.5 \frac{Ec}{\dfrac{g}{s} - \dfrac{s}{g}} \cdot \frac{h}{i}$$

for a lever of the second order

$$\beta = 2.5 \frac{c}{S_{max}} = \frac{1}{S_{max}} \cdot \frac{\sigma}{3E} \cdot \frac{i}{h} \left(\frac{g}{s} - 2 \right) . \tag{14}$$

where

$$\sigma = 7.5 \frac{Ec}{\dfrac{g}{s} - 2} \cdot \frac{h}{i} .$$

For systems in which β is assumed to be equal for all the levers, we have for the levers of the first order

$$\sigma = 7.5 \frac{Ec}{\dfrac{g}{s} - \dfrac{s}{g}} \cdot \frac{h}{i} \cdot \frac{1}{1 + \dfrac{s_1}{g_1} + \dfrac{s_1 s_2}{g_1 g_2} + \ldots} ; \tag{13 a}$$

Fig. 4

for the levers of the second order

$$\sigma = 7.5 \frac{Ec}{\frac{g}{s}-2} \cdot \frac{h}{i} \cdot \frac{1}{1+\frac{s_1}{g_1}+\frac{s_1 s_2}{g_1 g_2}+\ldots}. \qquad (14\,a)$$

Here values g and s without a subscript refer to the lever under consideration

It follows from comparing Eqs. (13), (14) with (13a), (14a) that additional levers produce a relatively small effect; expressions (13) and (14) can be used as criteria of stiffness both of single levers and systems of levers.

The expressions thus obtained represent conditions which provide a sufficient stiffness of the lever; the effect of their sagging can be compensated in such a manner that they do not exceed the limits of tolerance. Simultaneously the conditions $\sigma < \sigma_p$ where σ_p is the limit of proportionality, must be fulfilled.

In the case of steel levers ($E = 2.1 \cdot 10^4$ kg-wt/cm^2) we have for the levers of the first order:

$$\sigma = 160 \frac{c \cdot 10^3}{\frac{g}{s} - \frac{s}{g}}$$

for levers of the second order:

$$\sigma = 160 \frac{c \cdot 10^3}{\frac{g}{s} - 2}.$$

Assuming for the sake of simplicity that $h/i = 1$, let us calculate the values of σ for balance levers at a set error of 1 and 0.5%. The results of the calculations are given in Fig. 4.

It follows from the graph that the normally recommended value of $\sigma_{calc} = 3/4\,\sigma_p$ ensures compensation of the bending effect only for a leverage ratio of $g/s < 14$ and a permissible error of 1%. If the tolerance is 0.5% or the leverage ratio larger, the value of σ_{calc} should be decreased to less than 10 kg-wt/cm^2.

Thus, the specification of substantiated values for the stiffness of levers, taking into consideration the compensation of the balance errors, is necessary and possible.

MEASUREMENT OF ANGULAR DISPLACEMENTS OF MACHINE
DETAILS WITH REVERSIBLE ROTATION

L. I. Solov'ev

In connection with the production of new high-speed machines, experimental methods of determining the dynamic and kinematic characteristics of machines are acquiring an increasing significance. For accurate recording of angles of rotation, angular velocity, and irregularities of rotation, electrical measuring methods with the use of angular displacement transducers are now being widely employed. It is normal practice to use for this purpose photoelectric and magnetoelectric transducers, commutator disks, and transducers with resistances in the form of rheostats or slide wires placed circumferentially.
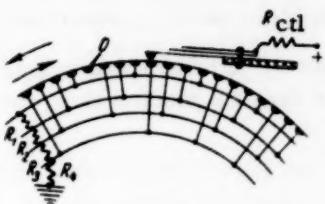
Fig. 1
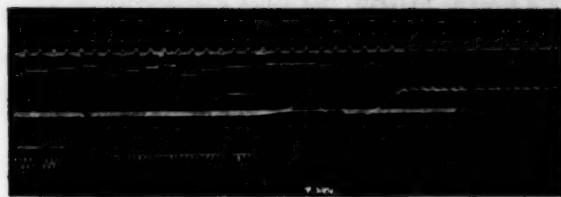
Fig. 2

Number of turns	Number of segments	Diameter of the wire	External diameter of the disk	Width of the groove	Depth of the groove before grinding	Hole diameter
n	m	d	D	B	H	d_1
360	4	0.5	100	0.53	0.45	0.55
360	4	0.65	140	0.68	0.55	0.7

Measurements of details with reversible rotation is even more difficult, since in this case it is also necessary to determine the direction of rotation. The use of resistance transducers solves this problem, but does not provide great accuracy, since the recording of one turn takes up a film width, which for the widely used oscillograph MPO-2 only amounts to 25 mm. Recording with other types of transducers is longitudinal and provides greater accuracy of measurement, but does not give a direct indication of the direction of rotation. For measuring angles of rotation in details with reversible rotation we have developed, constructed, and tested out in the Leningrad Branch of the Scientific Research Institute of Light and Textile Engineering a special transducer. It consists of a thin commutator disk whose contacts are connected in a certain sequence to a four-terminal network (Fig. 1). Segments are connected to each other through resistors R_1, R_2, and R_3 and the last segment is connected through resistor R_4 to the frame. The supplies are connected through a brush and control resistance R_{ctl}. With this arrangement the current flowing through the brush from the contacts will rise in steps when the disk is rotating in one direction and will decrease when the rotation is reversed. Figure 2 shows an oscillogram with a recording of two angular displacements measured by means of a sectionalized commutator disk. The rising or falling level of the steps provides an indication of the change in the direction of rotation. In order to record the beginning of reckoning, one of the contacts is either disconnected from the segments or left out altogether (contact "0" in Fig. 1). Its recording in Fig. 2 is marked by figure "0".

The angular sectional transducer is made of a vinyplast disk 3 mm thick, and fixed to a steel hub. Contact segments are obtained by winding copper wire brand PÉ. The finishing transducers had an accuracy of 1°, and were wound in four sections. First the external diameter D of the disk had grooves cut in it of width B and depth H. At a distance of 4-5 mm from the outside edge holes of diameter d_1 were drilled, their number being equal to that of the grooves. The winding of a segment is done by pushing the wire through the hole and placing it in the corresponding groove. At the points where the wire is bent both in the holes and grooves the edges are bevelled to $0.4 \times 45°$. The wire is carefully bent at the corners by means of a wooden planishing hammer. After all the segments have been wound the wire is settled in the grooves by tapping it gently. Next the winding is shellacked and, after drying, the circumference of the disk is ground until the diameter of the indented wires is reduced to about 0.4-0.45 d (d being the diameter of the wire).

The data on the construction of the transducer is given in the table.

In addition, slots are cut in the disk for type VS resistors. The values of the resistors are $R_1 = R_2 = R_3 = 100$ ohm, $R_4 = 330$ ohm.

The grooves were milled by means of a dividing head and the holes drilled on a round table. Calibrations have shown that the errors in the pitch did not exceed 5'. The aggregate error depends on the accuracy of the attachments and can be determined from a graph of deviations plotted from the calibration data.

The brush was made in the form of a spring consisting of three blades 0.2 mm thick with a silver contact, whose end was ground at an angle of 100-120° with a radius of curvature of $r = 0.2$ mm. The power was supplied by a storage battery. By using a type II oscilloscope loop it was possible to record signals of 3000 cps.

When the recording is deciphered the direction of movement should be taken into account; moreover when the rotation is in one direction the counting should be taken from the time the contacts close, and when the rotation is in the opposite direction, from the time they open.

MEASUREMENT OF THE NUMBER OF TURNS WITHOUT
LOADING THE AXLE

E. A. Zel'din

An instrument using a photoelectric reflecting transducer with a photoconductor was developed by the Krylov Central Scientific Research Institute for measuring the speed of rotation of details which are difficult to get at or cannot be loaded. The measuring range extends up to 7000 rpm and the error is ± 1 revolution.

The instrument can be made even in primitive workshops. The electrical circuit does not contain any adjustable elements. In appearance the photoelectric transducer consists of two tubes which are closed at one end and carry an illuminating lamp (12 v, 15 w) and a photoconductor (FS-A1, FS-D1), respectively. At the front end the tubes have short focal length lenses.

The lamp shines on the shaft with white and black stripes painted on it. When the shaft is turning, the photoconductor produces pulse voltages at the repetition rate of the stripes. The measurement of the speed of rotations amounts to counting by means of an electromechanical counter SB-1m/100 the number of pulses during a certain interval of time (15 seconds). For measuring the test time, an ordinary alarm clock was used with a slight alteration: a silver pin was pressed into its lever fork, and above the pin a flat spring was fixed on an insulated bushing. The movement of the clock drives the pin against the spring, producing a short electrical contact period of 0.6 second. This contact controls a biased blocking oscillator.

At the beginning of the measurement the first pulse of the blocking oscillator operates the tube, which amplifies the signals from the photoelectric cell, and starts off the stepped switch ShI-25, whose operation by the blocking oscillator disconnects the circuit on the 25-th step of the switch.

The electromechanical counter measures the number of revolutions per minute. The maximum speed of measurement is determined by the resolution frequency of the counter SB-1m/100-120 cps (according to the specification, 100 cps). If decatrons or scaling circuits are used, the frequency can be increased. Experience has shown that the instrument can also be used for measuring to and fro and pulsating movements.

MEASUREMENT OF SMALL DIFFERENCES IN THE ANGULAR
VELOCITIES OF TWO PULLEYS

V. V. Nikiforov

When investigating experimentally the behavior of various devices it is often required to measure small differences in the angular velocities of two pulleys.

Such cases arise when measuring, for instance, friction drives or plotting curves of belt drive slips, when it is necessary to determine the slipping

$$\epsilon = \frac{n_1 - n_2}{n_1} \cdot 100\%,$$

where n_1 is the angular velocity of the driving pulley; n_2 is the angular velocity of the driven pulley (it is assumed that the diameters of the pulleys are equal).

If the driving pulley is rotating at 1400 rpm, a slip of $\epsilon = 1\%$ is equivalent to 14 rpm, which is impossible to measure by direct reading mechanical tachometers operated by the driving and driven shafts (in addition to the difficulty of estimating readings with such accuracy, it should be remembered that the tachometers have a certain error in measurement which in this case is of the same order as the difference in velocities).

A widespread method of determining such small velocity differences is the use of stroboscopes, whose flash lamps are made to light up in synchronism with the driving pulley revolutions by means of a switch operated by the pulley.

If the flash lamp is used to light up the driven pulley on which a white strip is fixed, this strip will appear to revolve slowly in the opposite direction to the pulley rotation (it is assumed that the velocity of the driven pulley is smaller than that of the driving one).

By measuring on a stop watch the period of one apparent revolution of the strip it is possible to determine the difference of the angular velocities of the pulleys. Thus, if t_1 is the time in seconds for a complete revolution of the driven pulley strip, it means that in this time the driven pulley has made one revolution less than the driving one. In one minute the difference in revolutions will amount to

$$n_1 - n_2 = \frac{60}{t_1}.$$

The slip in the belt transmission will be

$$\epsilon = \frac{n_1 - n_2}{n_1} \cdot 100\% = \frac{60}{n_1\, t_1} \cdot 100\%.$$
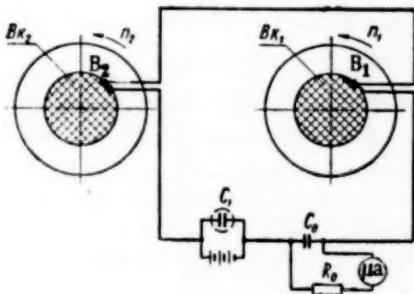
It will be easily seen that in this method an error in measuring the angular velocity of the driven pulley will lead to large errors in determining ϵ.

Instead of the stroboscope, neon lamps can be used with equal success, since they have no inertia due to heat.

The inconvenience of the above methods of measuring a slip consists in the necessity of the observer being near the driven pulley and the impossibility of measuring the slip directly on a pointer instrument.

These defects are eliminated in the method proposed by the author of measuring angular velocities at a distance – a method whose electrical circuit is shown in the figure attached.

Textolite rings are fixed to the short ends of each pulley; these rings carry contacts B_{k1} and B_{k2} which short the double contact brushes B_1 and B_2, respectively. At the instant the two pairs of brushes are shorted at the same time, capacitor C_0 is charged rapidly from capacitor C_1. As the result of the difference in the velocity of the pulleys, brushes B_1 and B_2 will be shorted one by one and will again be shorted simultaneously only when the driven pulley slips behind the driving one by one complete revolution. During the whole of this time, the circuit remains open and capacitor C_0 discharges through the resistor R_0 and the microammeter. The pointer of the instrument is deflected rapidly to the right during charging but returns slowly to zero during discharging.

Before the pointer reaches zero it is again deflected to the right (the circuit has been made and capacitor C_0 charged), and this keeps on repeating itself. The slip is then measured by the position on the scale which the pointer reaches during the discharging of the capacitor. The instrument can be easily calibrated by measuring on a stop watch the time between the consecutive throws of the pointer, which correspond to the time the driven pulley takes to slip one complete revolution behind the driving one, and calculating the velocity difference from it .

The ratio of the length of arc occupied by each revolving contact to the entire circumference must not exceed the ratio of the maximum expected difference of velocities to the driving pulley velocity.

This circuit was used in the details laboratory of the Bauman Moscow Higher Technical School for measuring belt drive slips. The parameters of the circuit are: supply voltage of 96 v obtained from a selenium rectifier; capacitor C_1 — electrolytic of 40 μf; capacitor C_0 — mica of 2 μf; resistor $R_0 = 1.3$ meg; microammeter of 75 μa full scale deflection (calibrated in slip values).

HIGH PRECISION TORSION METER

A. V. Gur'ev

Instruments for measuring strains in materials should not only be sensitive and reliable, but should have a large measuring range and a linear scale. A highly sensitive torsion meter with a linear scale over the entire wide twist angle range was designed and constructed for static twist measurements in the Stalingrad Mechanical Institute.

The torsion meter (see figure) consists of two separable parts 1 and 2, which serve as mountings, which prior to fixing the instrument on the sample, are held together by screw 3. Each mounting is fixed on the sample by means of four moving pointed jaws, 4. The centering and fixing of the instrument on the sample is made automatically by screwing up nuts, 5, and forcing sleeves, 6, which have a conical internal surface, over the jaws, thus securing them firmly by means of their pointed ends to the sample.

The mountings, nuts 5, and sleeves 6, have slots cut in them which serve to place and fix the sample in the mountings. Such a construction provides the possibility of using samples with considerable deviations in their diameter. For instance, the above torsion meter can be used for testing round samples with a diameter of 9-11 mm. Variations in the diameter of samples do not produce changes in the magnification of the instrument—changes which occur in other types of torsion meters.

After the instrument has been fixed to the sample, screws, 3, are unscrewed by hand (but not taken out of the mounting, 2) thus, disconnecting the two mountings from each other. Bracket, 7, is rigidly fixed to mounting, 1, and holds extensometer, 8. Mounting, 2, carries dog, 9, which rests with its pointed end against quadrant, 10.

The quadrant can rotate on mounting, 1, about the axis of the sample. A thin flat spring, 11, is connected with one end to the quadrant and with the other to the moving rod of extensometer, 8.

When torque is applied to the sample, mounting 2 rotates with respect to mounting 1, and turns the quadrant through a certain angle. The measuring spring is wound onto the quadrant and produces a displacement of the extensometer moving rod proportionate to the angle of twist of the sample, thus providing a constant magnification for the torsion meter over the entire range of strain measurements. In order to provide a constant tension for the measuring spring, either the extensometer is mounted upside down or the direction of the extensometer tensioning spring is reversed, so that the extensometer moving rod is pushed by the spring inwards instead of outwards.

The basic technical characteristics of the torsion meter are: calibration in 0.0002 of a radian (when an extensometer with a graduation of 0.01 mm is used); the maximum twist angle that it is possible to measure with one fixing of the instrument is 14°; the measuring distance of the instrument is 10 cm.

Experience in the use of the instrument has shown that it is reliable, accurate, and convenient in use. Its linear scale makes it possible to use the instrument not only in the elastic range where the strains are small (for instance,in measuring the modulus of tangential elasticity) but also in the range of plastic deformations.

CHECKING TRACTION DYNAMOMETERS

N. N. Tanin

Great difficulties are encountered in the repair of industrial traction dynamometers, owing to the lack of appropriate means for testing them. A repaired dynamometer is usually tested by means of a hoist, a pan,and reference weights. After the pan if fitted and calibrated, reference loads of 500, 1000, 1500 kg, etc., in 20 kg steps, made up of grade 3 weights, are placed on the pan. Every time the load is changed, 3-4 men have to hoist up and lower the pan again. If the dynamometer under test is found to be outside the tolerance, it has to be taken down, the load taken off, the required alteration made.and the dynamometer checked again. For each dynamometer at least 18 tons of weights have to be moved.

In order to improve this unproductive method of checking, we have constructed at the weighing equipment repair shop of the Leningrad Metal plant a testing apparatus which was passed in State tests and approved for use.

The measurement error of this equipment is ± 0.2%. This error is perfectly satisfactory for testing and adjusting industrial dynamometers, since their permissible error amounts to ± 2%.

The test apparatus (see figure) consists of a weighing lever mechanism of the type of no-loose-weight small crane scales, mounted on a common frame with a gear assembly. The external dimensions of the equipment are: height 1500 mm, length 1200 mm, width 250 mm, and total weight 250 kg. The advantages of the equipment are: the floor space is reduced; the man power decreased to one person; the testing time cut down to 1/10 or 1/12 of the original; smooth loading and unloading is ensured (all jerks eliminated); it is simple and safe in operation.

The scales of this weighing mechanism are: the main scale of 0-3 tons in steps of 100 kg, auxiliary scales—a) from 0-100 kg in steps of 10 kg, and b) from 0-10 kg in steps of 1 kg. Such a combination of scales provides the possibility of making any required tests.
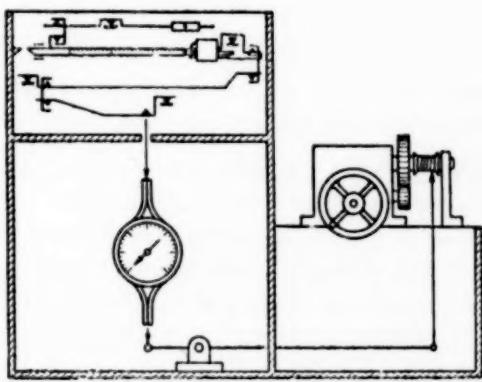
The method of testing a dynamometer on this equipment is: first the dynamometer is suspended from the weighing mechanism and the scale is calibrated (in the initial position the weights and the scales must be in the zero position); then the lower link of the dynamometer is attached to the gear assembly lever, the weight on the scale arm is placed at 3 tons, and the dynamometer is stressed by the operation of the gear assembly (done by hand or an electric motor) until the required load is smoothly attained; the reading of the dynamometer is then checked against the setting of the scale; the dynamometer is left under load for a certain time: its error is determined simultaneously; finally, the load is taken off, and the dynamometer and weighing mechanism returned to the initial position; from this position the step-by-step testing of the dynamometer is then started by loading it in steps corresponding to its scale graduations from 0 to 500, 1000, 1500, and finally, 3000 kg. A similar sequence is observed in reducing the load from 3000 to 2500, 2000, etc., to 0 kg. Such a series of tests of the dynamometer is repeated three times. After three such tests the equipment is returned to zero and disconnected.

By means of an additional device this equipment can be made universal, measuring both tension and compression.

THERMOTECHNICAL MEASUREMENTS

THE PROBLEM OF UNITS FOR MEASURING THERMAL QUANTITIES

S. M. Skuratov

The necessity of standardizing units in the sphere of thermal measurement is long overdue. In this connection it is necessary to note the important part played by GOST 8550-57 on "Thermal Units," which establishes the absolute joule as the basic unit for measuring quantities of heat.

The problem of using the joule as a thermal unit has been raised a long time ago. However, even at present a complete changeover to the joule as the only permissible unit in all the branches of thermal measurements is impossible owing to the lack of popularity of this unit and the widespread use of the calorie, this long-established unit of heat.

It is, therefore, perfectly justifiable that GOST 8550-57 should leave the calorie as a nonsystem unit, at the same time depriving it of its physical significance, which it had when it was first established (its relation to the thermal capacity of water). The calorie is determined by GOST 8550-57 only in its relation to the joule as $1\ cal = 4.1868$ joules.

The reasons for adopting precisely this relation between the calorie and the joule by the GOST are set forth in [1]. Briefly it can be stated that this relation is the conversion into absolute joules of the relation adopted by the 1929 International Conference on the properties of steam for

$$1\ cal = 1/860\ int\ w\text{-hr} = 4.1860_5\ int\ joules.$$

Thus, this relation had been accepted a long time ago in steam power work.

The conditions in thermomechanical measurements and the closely related and diverse branches of chemical thermodynamics are completely different. In all these spheres of measurements the relation $1\ cal = 4.1840$ joules has been used extensively and for a long time in the USSR, and not a single author (prior to the GOST) used $1\ cal = 4.1868$ joules.

The changeover of these spheres of measurement to the new relation would not, therefore, be advisable, since it could cause difficulties in using the existing numerical data.

The history of the relation $1\ cal = 4.1840$ joules is the following: in 1934 the Permanent International Thermochemical Commission, in view of the existence at the time of two electrical systems of units (the international and the absolute) did not consider it possible to recommend to all the scientists to desist from using the calorie (the Commission considered the 15°C calorie most widespread in thermochemical measurement at the time) and provisionally preserved it as a unit of measurement, recommending the relation $1\ cal_{15} = 4.1833\ int\ joules = 4.1850$ abs joules (according to the best estimates at that time $1\ int\ joule = 1.00040\ abs\ joules$).

In later work in estimating the thermal capacity of water it was considered that 4.1833 int joules did not correspond to the quantity of heat required to raise the temperature of 1 g of pure water from 14.5 to 15.5°C (i.e., cal_{15}). From the critical evaluation of the most accurate work (a very careful evaluation of this work was carried out in 1950 by Haas; the values established by him were approved by the International Weights and Measures Committee in 1950) it would appear that at the present time we should take 4.1855 joules as the value of the cal_{15}. Remembering, however, that the calorie is only preserved as a unit of measurement "temporarily," it is much more sensible (as has been done by many authors, especially in the USA) to forget about the physical interpretation of the calorie and preserve a constant relation between the calorie and the joule.

Since 1948 the international system of electrical units is no longer used anywhere in the world and all the measurements are made in absolute units. The relation between absolute and the international joule was taken to be:

$$1 \text{ int joule} = 1.00019 \text{ abs joules.}$$

Therefore, at the present time in works on thermochemistry and chemical thermodynamics it is advisable to adopt the following relation between the calorie and the absolute joule:

$$1 \text{ cal} = 4.1840 \text{ abs joules.}^*$$

The use by all the authors who work in this sphere of this particular relation will at least preserve the degree of consistency of numerical data attained at the present time.

It is necessary to stress once more that on the basis of GOST 8550-57 all the measurements of thermal quantities should be made in joules, and, if calories are used, the author should state what relation between calories and joules he is using.

Expressing the results of thermochemical measurements in joules should not cause any difficulties, since most of the modern calorimeters are either directly calibrated by electrical current or by means of known thermal effects, which can always be expressed in joules.

LITERATURE CITED

[1] B. I. Pilipchuk, Izmeritel'naya Tekhnika No. 1 (1959).* *

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* It would be more rigorous to take this value as 1 cal = 4.1833 · 1.00019 = 4.1841 abs joules. However, in very many works the relation given in the text (4.1840 abs joules) is used. The difference in these values (0.0025%) is of no importance even for the most accurate modern measurements.

* * See English translation.

ELECTRICAL MEASUREMENTS

A BALANCED VOLTMETER WITH A CRYSTAL DIODE

D. N. Livshits

When in a conventional balanced voltmeter circuit the thermionic diode was replaced by a crystal one, it was found that the stability of the voltmeter with time was relatively good and its reading little affected if the crystal diodes were changed.

It is also known that other crystal diode voltmeter circuits do not possess these properties, since their readings depend to a considerable degree on the deviations of the diode parameters when the diodes are changed and also depend on temperature variations.
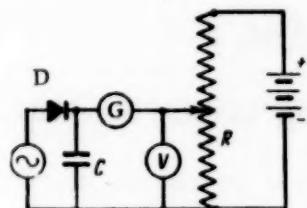
Fig. 1
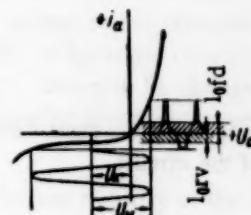
Fig. 2

A large number of germanium diodes of various types, whose volt-ampere characteristics were previously plotted, were tested in a model of this instrument. Despite the large deviations in the parameters of several diodes of the same type, the readings of the voltmeter only differed from each other on an average by ±1%.

Tests have shown the possibility of using crystal diodes for relatively accurate measurements of ac voltages over a wide frequency range.

Analysis of the Circuit Operation. In order to clarify the processes taking place in the circuit when voltages are measured, let us dwell on certain relations which characterize their operation.

It is known [1, 2] that the volt-ampere characteristic of the crystal diode can be represented by the formula:

$$i = I_s (e^{KU} - 1). \tag{1}$$

Here i is the diode current; I_s is the saturation current; U— the voltage applied to the diode; $K = q/kT$ is a diode parameter where q is the charge of an electron, k is Boltzmann's constant and T is the absolute temperature.

Figure 1 shows the schematic of the instrument. Figure 2 is the diagram of the currents and voltages in the circuit at balance.

At the instant the diode has two voltages applied to it, the measured voltage $u_\sim = U_M \cos \omega t$ and the compensating dc voltage $|-U_k|$. Taking this into account and after transformations it is possible to represent (1) in the form:

$$i = I_s \left\{ e^{-KU_k} [I_0 (KU_M) + 2 \sum_{n=1}^{n=\infty} I_n (KU_M)] - 1 \right\}.$$

It follows from the above that the direct component of the rectified current is

$$I_0 = I_s \left[I_0 \, (KU_M) \, e^{-KU_k} - 1 \right].$$ (2)

Fig. 3.

In these formulas $I_0(KU_M)$ is the modulus of the zero order Bessel function of a purely imaginary argument; and $I_n(KU_M)$, the harmonic components of the rectified current, are moduli of a Bessel function of the n-th order.

Since balance occurs when there is no direct current flowing through the galvanometer (Fig. 1), it is possible to represent this condition as follows:

$$I_0 = I_{0fd} - I_{0rv} = 0$$ (3)

Here I_{0fd} and I_{0rv} are the direct components of the direct and reversed rectified current (see Fig. 2).

In conjunction with this it is possible to write

$$I_0 = I_s [e^{-KU_k} \, I_0 \, (KU_M) - 1] = 0,$$

whence

$$e^{KU_k} = I_0 \, (KU_M) \quad \& \quad U_k = \frac{\ln I_0 \, (KU_M)}{K}.$$

Dividing the left and the right hand side of above expression by U_M, we obtain an expression for the voltage transfer constant of the circuit

$$K_d = \frac{U_k}{U_M} = \frac{\ln I_0 \, (KU_M)}{KU_M}.$$ (4)

Relation (4) can be represented in the form of curves $K_d = f(U_M)$ or $K_d = f(U_{eff})$ which represent the dynamic characteristics of the circuit.

Saturation current I_s does not figure in expression (4). This fact helps us understand why the deviations of the parameters of crystal diodes and their changes with temperature have no effect on the stability of the dynamic characteristics of the instrument and its readings.

Variations of the diode parameter K with small temperature changes which normally occur in practice have but a small effect on the readings of the instrument.

Let us examine briefly the physical processes which occur in the circuit at balance.

It is known [2, 3] that the saturation current I_s of a crystal diode is proportional to the conductivity of the semiconductor material of the diode. Conductivity σ in turn depends on the mobility μ of the current carriers and their concentration n and the relationship $\sigma = qn\mu$ (where q is a charge of an electron). In [2, 3] the following relations of the mobility and concentrations of current carriers to temperature in extrinsic semiconductors (the germanium diodes used in the circuit belong to this class) are given:

$$n \simeq \left(T^{-\frac{3}{4}} e^{-\frac{\Delta E_0}{2KT}} \right); \quad \mu \simeq T^{-\frac{3}{2}}$$

where ΔE_0 is the excitation energy of an electron.

On the basis of these relationships it is possible to draw the conclusion that conductivity rises with temperature, since the concentration of current carriers, which is proportional to conductivity, grows exponentially with
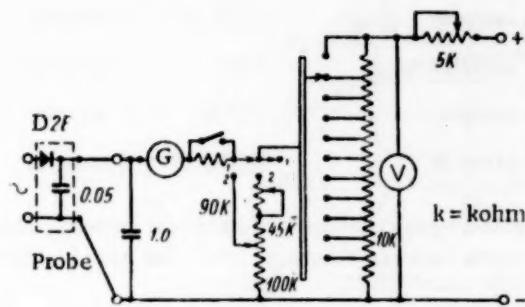
Fig. 4
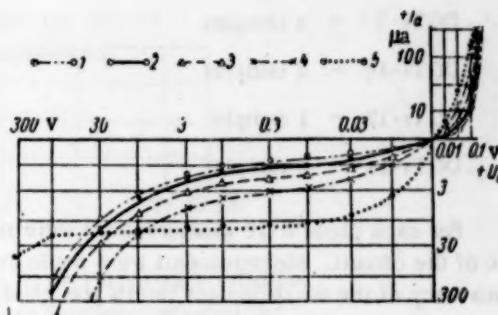
Fig. 5. 1) D2E (one model); 2) D2E (typical);
3) D1 (typical); 4) DGTs (typical); 5) DGTs-27
(typical).

temperature and the mobility of the current carriers decreases according to a low-value power law and thus has little effect on conductivity.

This reasoning holds for small variations of temperature with which the instruments work in practice.

The dispersion of the parameters of semiconductor diodes is mainly due to variations in the conductivity of the basic semiconductor for various diodes.

The effect of these phenomena on conductance is conditioned by the fact that conductivity rises with temperature both in the forward and reverse directions. Figure 3 shows the nature of the variations of the volt-ampere characteristic of type D2E diodes with temperature. A similar variation in the static characteristic will be observed when one diode is replaced by another, since the conductivity will thus also be changed which differs from diode to diode and depends on the variations in the concentration of impurity atoms produced in the manufacture of the original semiconductor [4].

These physical processes are, it would appear, the main reason for the stability of the instrument readings.

In fact, let there be, for some reason or another, a change in the conductivity of the diode and its volt-ampere characteristic (curve 2 in Fig. 3; and curve 1, the initial volt-ampere characteristic). This will lead to a simultaneous rise in the direct components of the rectified current both in the forward and reverse directions, thus hardly changing their difference. Hence the conditions of balance do not change:

$$I_0 \, fd - I_0 \, rv = I'_0 \, fd - I'_0 rv = I_0 = 0$$

Thus, "self-compensation" is occurring in the circuit, which means that the readings of a balanced voltmeter with semiconductor diodes depend but little on changes in temperature or the changing of the diodes for others with different characteristics.

These processes must also occur in other semiconductor diode circuits, but their stabilizing effect is stronger in this circuit owing to the compensation method of measuring the voltage.

Test Results of an Instrument Model. Figure 4 shows the circuit of the model. The instrument consists of a combination of a high frequency probe and a simplified dc compensator. The compensator consists of a stepped potential divider and a zero indicating galvanometer. At the output of the divider, known dc voltages are obtainable.

In parallel with each of the potential divider taps it is possible to connect a potentiometer with a dial calibrated in values of the measured voltage, corresponding to a set compensation voltage. In calibrating and measuring the circuit, the ac voltage was measured by means of a standard compensation voltmeter OKB-2, whose relative error is OKB-2 $\Theta_{OKB-2} = \pm (0.2 + \dfrac{0.08v}{U_{eff}}) \cdot 100\%$. The compensator provides a dc voltage setting with an error not exceeding ± 0.8%.

The following germanium diodes were tested out in the circuit:

DGTs-7 — 3 samples	D2B — 1 sample	D1B — 2 samples
DGTs-10 — 2 samples	D2B — 4 samples	D1E — 3 samples
DGTs-12 — 1 sample	D2G — 1 sample	D1Zh — 1 sample
DGTs-14 — 1 sample	D2E — 5 samples	DGTs-27 — 2 samples

For each diode 6-10 measurements were made of its volt-ampere characteristic and the dynamic characteristic of the circuit. Measurements were made at different times between February, 1956, and March, 1958. The consistency of the measurement results was good.

The static characteristics of the germanium diodes shown in Fig. 5 differ considerably from each other. The points which served to plot the characteristics correspond to the arithmetic mean of the measurement results of static or dynamic characteristics of several diodes of the same type. For comparison purposes a static characteristic of a D2E diode is also given, which differs from the typical characteristic of the D2E diodes.

Yet the dynamic characteristics of the circuit with the same diodes almost coincide. (Fig. 6).

Thus, the small dependence of the circuit on the diode parameter variations is confirmed.

Two junction type diodes DGTs-27 were also tested. The possibility of using these diodes in order to extend the range up to 150 v (U_{eff}) at audio frequencies was shown. It will be seen from Fig. 6 that the dynamic characteristics for this type of diode beginning with $U_{eff} = 2$ v, coincide with the characteristics of the other diodes.

The frequency characteristics of this circuit were determined by means of the OKV-2 meter, the low-power meter IMM-6 which was checked against OKV-2, and oscillators ZG-12, GSS-6, and GSS-17.

The frequency characteristic shown in Fig. 7 is plotted on points corresponding to the arithmetic mean of the characteristics of five D2E and two DGTs-27 diodes taken with a measuring voltage of $U_{eff} = 0.1$ v. The dispersion of readings for any of the diodes did not exceed ±0.5%.

It is interesting to note that the dynamic characteristics of the circuit with a thermionic and crystal diode are expressed by the same relationship (4). Therefore, many of the propositions derived in [5] can be applied to circuits with crystal diodes.

Since thermionic diodes work at a high temperature of the heater, their parameter K is about one quarter of that of germanium diodes. Hence the transfer constant of circuits with germanium diodes will be higher than those with thermionic diodes, especially at low voltages [see (4)].

Tests have shown that with a measured voltage of $U_{eff} = 0.1$ v the voltage transfer constant of a compensation circuit with a thermionic diode amounted to 30% and with a crystal diode to 64%. This phenomenon indicates the possibility of measuring very small voltages by means of the latter circuit. Thus, for instance, in a model using galvanometer M-95 it was possible to measure voltages of the order of 10 mv.

The relative error of measurement ξ_Σ was caused in the model mainly by the error in adjusting the compensating voltage, which error did not exceed (see above) $\xi_k = \pm 0.8\%$, and by the instability of the dynamic characteristic, which the tests have proved not to exceed the value of $\xi_d = \pm 0.7\%$ for the D2E diode. Therefore, it is possible to write

$$\xi_\Sigma = \sqrt{\xi_k^2 + \xi_d^2} = \sqrt{(0.8)^2 + (0.7)^2} = 1.05\%.$$

It is assumed that the relative error of the model is free of systematic errors whose effect it is possible to estimate.

The input impedance of the circuit can be represented as a parallel connection of resistance R_{in} and capacitance C_{in}.

It has been shown in [6] that the input impedance of circuits with crystal diodes is greatly affected by the reverse resistance of the diode, which may amount to a few megohms. The R_{in} for the circuit under consideration is of the same order.

C_{in} is determined in the main by the transfer capacitance of the diode, which for type D2E diodes is of the order of $1 \mu\mu f$.
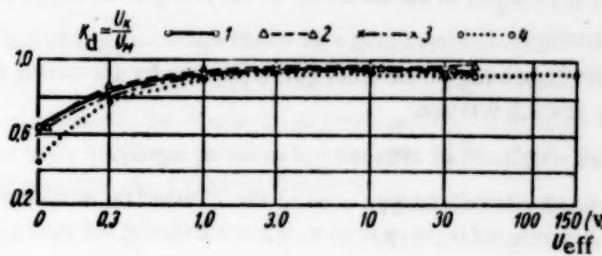
Fig. 6. 1) D2 (typical); 2) D1 (typical); 3) DGTs (typical); 4) DGTs-27 (typical). $K_d = U_k / U_M$ is the voltage transfer constant of the circuit; U_{eff} is the effective value of the measured voltage.
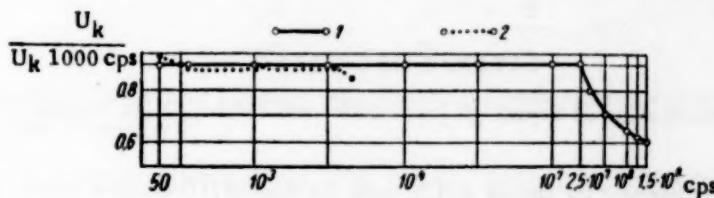
Fig. 7. 1) D2E (typical); 2) DGTs-27 (typical); the measured $U_{eff} = 0.1$ v = const.

It is shown in [7] that this capacity does not remain constant during the operation of the diode and depends on the frequency, temperature, and the voltage applied to the diode.

Tests have shown that the circuit reading is not affected by variations of the blocking capacity in the limits of 0.05 to 2 μf and of the resistance across which the compensation voltage is obtained from 100 ohm to 100 kilohm.

The raising of this resistance to 100 kilohm tends to increase the input impedance of the circuit, stabilize its reading, and decrease the power supplied by the voltage compensation source.

The parameters of the circuit components (shown in Fig. 4) are optimum ones and provide conditions for an effective "self-compensation" of the circuit.

On the basis of the tests conducted with the model, the author of this article constructed a sample voltmeter with the following characteristics.

Measured voltages: 0.03-30 v (U_{eff}) in the range of 50 cps to 130 Mc. Above 25 Mc a frequency correction obtained from the frequency characteristic is used. The correction remains valid with ageing. The audio frequency range, when DGTs-27 diodes are used, is extended to 150 v.

The basic referred measurement error of the instrument for each of the seven ranges of 0.3, 1.0, 3.0, 10.0, 30, 50, and 100 v (effective values) does not exceed ± 1.5%. The readings of the instrument calibrated against an OKV-2 set did not deviate from it after 4 months by more than ±0.8%.

Since the voltmeter contains a simplified compensator and a potential divider it can be used for dc voltage measurements from 10 mv to 250 v with a high input impedance and an error not exceeding ± 1.0% on all the 11 measuring ranges, and also for checking tube voltmeters at the commercial frequency by means of another potential divider.

The probe of the instrument can be used in conjunction with the circuit dynamic characteristic graph and a high resistance compensator, for instance, compensator PPTV/1. Tests have shown the possibility of measuring in this manner voltages from 10 mv to 3 v with an error not exceeding ± 0.6% in the range of 50 cps to 150 Mc.

The weight of the instrument is no more than 3 kg, its external dimensions are 283 × 130 × 105 mm, and the probe is 100 mm long and 15 mm in diameter. The microammeter is type M-24, full scale deflection of 100 μa, grade 1.0; it can be switched into two positions: in one of them it is connected as a zero reading galvanometer and in the other as a voltmeter for checking the voltage at the divider input. In order to ensure accuracy,

the pointer of the instrument is arranged to be deflected to the last graduation of the scale for the correct divider input voltage.

A provision is made for connecting an external galvanometer for increasing the sensitivity and accuracy of measurements, especially in the 0.3 v range.

The instrument operates with both an internal and external supply.

The internal battery is the 75 AMTsG-22 type used in the "Turist" radio receiver. The dc power consumption does not exceed 0.5 w when measuring voltages up to 30 v. When measuring voltages up to 250 v, the power consumed is no more than 7 w.

Its advantage as compared with a tube voltmeter consists in the absence of the heater circuit and the elimination of zero setting and adjustment for the K parameter. The instrument is simple to calibrate and its calibration holds when diodes are changed. Commercial types of tube voltmeters are inferior to these voltmeters in the majority of their parameters.

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EFFECT OF THE INTERNAL TEMPERATURE OF A CONDUCTOR ON THE ACCURACY OF DETERMINING ITS ELECTRICAL RESISTANCE

F. N. Nikolaev

When a current flows through a conductor, heat is dissipated inside the conductor due to the transformation of electrical energy into heat. Hence a conductor through which an electric current is flowing can be considered as a body with an internal source of heat.

Changes of temperature with time at any point of a homogeneous body with an internal source of heat are represented by a differential equation

$$\frac{d\vartheta}{dt} = \frac{\lambda}{\gamma C} \nabla^2 \vartheta + \frac{W}{\gamma C}, \tag{1}$$

where W is the amount of heat dissipated in the body per unit time and volume; γ is the density of the body; C is its thermal capacity; λ is the coefficient of thermal conductivity; ϑ is temperature, ∇^2 Laplace operator.

Equation (1) shows that the change of temperature at a given point is determined in the first place by the heat coming from other points and in the second place by that provided by the sources of heat.

If an unchanging medium surrounds the conductor, a given point soon reaches a temperature at which no further change occurs, i.e., the body attains a so-called steady state with respect to temperature. Hence in such a case $d\vartheta/dt$ must be equal to zero and Eq. (1) takes the form:

$$\nabla^2\vartheta + \frac{1}{\lambda} W = 0 \tag{2}$$

or in cylindrical coordinates, if the axis of the cylinder coincides with the z axis:

$$\frac{d^2\vartheta}{dt^2} + \frac{1}{r} \cdot \frac{d\vartheta}{dr} + \frac{W}{\lambda} = 0. \tag{3}$$

The solution of this differential equation will provide the temperature at any point in the cylindrical conductor for a steady state condition.

For the solution of (3) let us assume that $d\vartheta/dt = u$, and multiplying both sides of Equation (3) by rdr, we have

$$r \frac{du}{dr} dr + udr + \frac{W}{\lambda} rdr = 0,$$

or

$$rdu + udr + \frac{W}{\lambda} rdr = 0,$$

or

$$d(ur) = \frac{W}{\lambda} rdr,$$

which after integration gives:

$$ur = -\frac{W}{\lambda} \cdot \frac{r^2}{2} + C_1 \tag{5}$$

or

$$\frac{d\vartheta}{dt} = -\frac{W}{\lambda} \cdot \frac{r}{2} + \frac{C_1}{r}. \tag{6}$$

and integrating again we have:

$$\vartheta = -\frac{W}{4\lambda} r^2 + C_1 \ln r + C_2, \tag{7}$$

where C_1 and C_2 are constants of integration.

We find from (5) that for $r = 0$, $C_1 = 0$.

Constant C_2 is determined from the condition that the amount of heat flow to a surface element, which according to the basic thermal conductivity equation is expressed by the formula

$$dQ = -\lambda \left(\frac{d\vartheta}{dr} \right)_{r=R} d_f d_t, \tag{8}$$

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is equal to the amount of heat which flows out of this surface into the surrounding space and is represented by the formula:

$$dQ = a\,(\vartheta_{r=R} - \Theta)d_f d_t.$$

(9)

By equating the right hand sides of Eqs. (8) and (9), we shall obtain surface conditions in the form

$$-\lambda\left(\frac{d\vartheta}{dr}\right)_{r=R} = a(\vartheta_{r=R} - \Theta),$$

(10)

where α is the coefficient of thermal conductivity; Θ is the temperature of the surrounding medium.

The conditions stipulated by (10) do not depend on the shape of the surface. They hold both for a steady state and variable condition of temperature.

By substituting in (10) the value of $d\vartheta/dr$ from (6) and the value of ϑ from (7) we have:

$$-\lambda\left(-\frac{WR}{2\lambda}\right) = a\left(-\frac{WR^2}{4\lambda} + C_2 - \Theta\right),$$

(11)

since under this condition r = R and $C_1 = 0$.

By solving (11) for C_2 we have

$$C_2 = \Theta + \frac{WR^2}{4\lambda}\left(1 + \frac{2\lambda}{aR}\right).$$

(12)

By substituting the values of the integration constants in equation (7) we obtain the final solution of the differential Eq. (3) in the form:

$$\vartheta = \Theta + \frac{WR^2}{4\lambda}\left(1 + \frac{2\lambda}{aR} - \frac{r^2}{R^2}\right).$$

(13)

It represents the temperature at any point of the cylinder at any distance r from its axis.

It follows from Eq. (13) that the temperature at the axis and at the surface and the difference between them is represented by the following formulas:

$$\vartheta_m = \Theta + \frac{WR^2}{4\lambda}\left(1 + \frac{2\lambda}{aR}\right);$$

(14)

$$\vartheta_0 = \Theta + \frac{WR}{2a};$$

(15)

$$\vartheta_m - \vartheta_0 = \frac{WR^2}{4\lambda}.$$

(16)

Thus, we have found that in the stable state the temperatures at points at various distances from the axis of the cylinder are different. Hence the electrical conductivity at these points will also differ and the current density along the cylinder cross section will also vary. Since the temperature decreases towards the surface of the conductor, the current density will increase towards the surface, i.e., with a positive temperature coefficient a phenomenon similar to skin effect will occur. Hence when the resistance of a conductor is estimated from temperature measurements at its surface, owing to the above-mentioned phenomenon a certain error is committed by taking the temperature of the medium surrounding the conductor or that of the conductor surface for the temperature of the conductor itself. In order to judge the value of this error let us find the effective temperature of the conductor, i.e., a temperature which we could consider as average for all the points of the cylinder. For this purpose let us revert to (13) and express the temperature of a point at distance r from its axis in terms of the density of the body at that point by formula:

$$\theta - \theta = \frac{dQ}{C\gamma dv} = \frac{dQ}{C\gamma 2\pi r dr},$$

(17)

where dv is the elementary volume per unit length of the cylinder under consideration (dv = $2\pi r dr$).

Equation (13) will then take the form:

$$dQ = \frac{2\pi R^2 C\gamma W}{4\lambda}\left[\left(1 + \frac{2\lambda}{\alpha R}\right) - \frac{r^2}{R^2}\right] r dr.$$

(18)

The total amount of heat which has accumulated in volume dv and is preserved in the cylinder in the steady state, will be expressed by the following equation:

$$Q = \frac{\pi R^2 C\gamma W}{4\lambda}\int_0^R \left[\left(1 + \frac{2\lambda}{\alpha R}\right) - \frac{r^2}{R^2}\right] r dr,$$

after integration it becomes:

$$Q = \frac{\pi R^4 C\gamma W}{4\lambda}\left(\frac{1}{2} + \frac{2\lambda}{\alpha R}\right).$$

(19)

By dividing both parts by $\pi R^2 C\gamma$, we obtain

$$\frac{Q}{C\gamma\pi R^2} = \theta_{eff} - \theta = \frac{WR^2}{4\lambda}\left(\frac{1}{2} + \frac{2\lambda}{\alpha R}\right).$$

From this expression we obtain the effective temperature for the entire cylinder

$$\theta_{eff} = \theta + \frac{WR^2}{4\lambda}\left(\frac{1}{2} + \frac{2\lambda}{\alpha R}\right).$$

(20)

This formula could have been obtained in a different manner, namely by substituting in Eq. (13) the ratio (r^2/R^2) by an equal ratio S_1/S_0, where S_1 is the cross-sectional area with radius r, and S_0 is the total cross-sectional area of the cylinder under consideration with radius R (the latter ratio can also be considered as a ratio of the masses of cylinders with radii r and R). Equation (13) will then take the form:

$$\theta = \theta + \frac{WR^2}{4\lambda}\left(1 + \frac{2\lambda}{\alpha R} - \frac{S_1}{S_0}\right).$$

(21)

The latter equation shows that the relation of the radial variations of temperature in the cylinder to the radial variations in its mass is linear. From this fact the conclusion can be drawn that the effective temperature for the whole cylinder will be the mean temperature between that of the axis and the surface of the cylinder.

By adding Eqs. (14) and (15) term by term and dividing both parts by 2, we find the effective temperature:

$$\frac{\theta_m + \theta_0}{2} = \theta_{eff} = \theta + \frac{WR^2}{4\lambda}\left(\frac{1}{2} + \frac{2\lambda}{\alpha R}\right).$$

(22)

which coincides with expression (20).

By comparing the right hand sides of Eqs. (13) and (22) we find

$$r = \frac{\sqrt{2}}{2}R,$$

(23)

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i.e., points whose temperature is equal to the effective temperature of the cylinder are placed at a distance from the cylinder axis equal to $r = (\sqrt{2}/2)R$.

Next, let us assume that in determining the resistance of the conductor we have measured its surface temperature. Then by subtracting from (20) Eq. (15) we shall find the correction for the measured temperature in the form:

$$\vartheta_{eff} - \vartheta_0 = \Delta\vartheta = \frac{WR^2}{8\lambda} .$$

(24)

The correction for the measured resistance in terms of percentages will be

$$\Delta R_0 = (\alpha'\Delta\vartheta + \beta'\Delta\vartheta^2...) \cdot 100\% ,$$

(25)

where α', β' . . . are resistance temperature coefficients; R_0 is the resistance of the cylinder portion under consideration.

It should be noted that in (25) the sum of the terms starting from the second is always smaller than the first. Hence this relation always holds

$$\Delta R_0 > 2\alpha \frac{WR^2}{8\lambda} 100\% .$$

Thus, assuming that

$$\Delta R_0 = 2\alpha' \frac{WR^2}{8\lambda} 100\% ,$$

(26)

we merely bolster the guarantee of accurate calculations.

Substituting the amount of heat dissipated by the internal sources in a unit volume, i.e., W, by the current density i and the conductivity κ' referred to 1 cm^3 according to the formula

$$W = \frac{0.24 i^2}{\kappa'}$$

and substituting it in (26) we obtain

$$\Delta R_0 = 6 \frac{i^2 R^2 \alpha'}{\lambda \kappa'} \% .$$

(27)

Formula (27) shows that a resistance correction for a conductor is directly proportional to the square of the current density and the square of the radius of a cylindrical conductor.

In order to be able to neglect the correction in determining the resistance with an error not exceeding 0.0001%, it is necessary to fulfil the condition

$$0.0001 \geqslant 3\Delta R_0.$$

By substituting the value of ΔR_0 from (27) we have:

$$0.0001 > 3 \cdot 6 \frac{i^2 R^2 \alpha}{\lambda \kappa'} .$$

(28)

Whence we obtain

$$R < \sqrt{\frac{0.0001 \lambda \varkappa'}{3 \cdot 6 l^2 a}}$$

or

$$R < \frac{1}{10^2 l} \sqrt{\frac{\lambda \varkappa'}{3 \cdot 6 a}}. \tag{29}$$

Let us use formula (29) for copper and manganin. For copper $\lambda = 300$; $\varkappa' = 57 \cdot 10^4$ and $\alpha = 0.004$; hence

$$R < \frac{4.9 \cdot 10^2}{l}.$$

For manganin $\lambda = 10$; $\varkappa' = 2.326 \cdot 10^4$ and $\alpha = 0.0002$. Hence:

$$R < \frac{2.5 \cdot 10^2}{l}.$$

A current density up to 4 amp/mm^2 is allowed for rheostat wire. For standard resistors the current density is 1/2 to 1/3 of this value. For current density of 4 amp/mm^2 we have in the case of copper $2R \le 2.5$ cm; and for manganin $2R \le 1.3$ cm. With a current density of 1.5 amp/mm^2 we have for copper $2R \le 6.5$ cm, and for manganin $2R \le 3.3$ cm.

In deriving formula (27) we have assumed that the cylindrical conductor in question was long enough for us to ignore the effect of heat dissipation by its ends on the distribution of the temperature in the cylinder.

In fact, for the effect of the cylinder end surfaces' dissipation to be of the same order as that of the side surfaces', these surfaces must be of the same order, i.e., $2\pi R^2 = 2\pi RL$, whence we obtain $L = R$, where L is the length of the cylindrical conductor.

Thus it is possible to state as a first approximation that the ratio of the effect of heat dissipation by the end surfaces of the cylinder to that of the side surfaces is equal to the ratio of the radius to the length of the cylindrical conductor.

CONCLUSIONS

1. When the resistance of homogeneous cylindrical conductors of 6.5 mm diameter for copper and 3.3 mm for manganin are determined at a current density of 1.5 amp/mm^2, the error of measurement due to temperature differences inside the conductor and at its surface can be ignored owing to their small values.

2. When the resistance of cylindrical conductors with diameters greater than 6.5 cm for copper and 3.3 cm for manganin are determined, the errors due to the above-mentioned cause must be corrected according to formula (27).

3. Formula (27) holds for sufficiently long homogeneous cylindrical conductors with a temperature coefficient whose sum of higher-power terms is not larger than the first term.

AN ELECTRONIC LOW TENSION SWITCH

E. L. Kantor

The electronic commutator under consideration is designed for simultaneous observation on an oscillograph screen of two voltage curves of an amplitude $U_{in} \geq 50$ mv. The gain of the commutator is $k = 20$. Its frequency characteristic is flat from 30 cps to 500 kc within ± 1db. It is supplied from a stabilized rectifier with 300 v at a total anode current $I_a = 80$ ma. The heater circuits must be balanced to ground.

The schematic of the commutator is shown in Fig. 1. The voltages which are to be switched, are fed from terminals In_I and In_{II} to the control grids of tubes T_2 and T_3. Negative voltages fed from the multivibrator tube T_5 to the suppressor grids of these tubes block them alternately, thus producing alternating amplified reproductions of the input signals in the common anode load R_4. The double diode T_1 serves as a dc restorer, and ensures that only negative voltages are fed to the suppressor grids of T_2 and T_3. Cathode follower T_6 provides a smooth control of the output voltages without noticeable phase distortion.
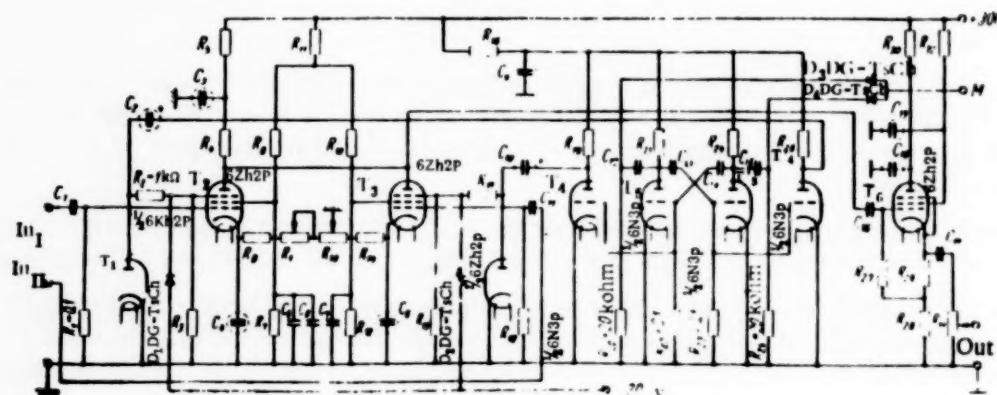
Fig. 1

In addition to the output (switched) voltages the blocking voltages (switching pulses) also appear across resistor R_4. For the switched pulses not to be distorted by the switching pulses the latter must have very flat tops. The pulses generated by the multivibrator do not satisfy these requirements (Fig. 2a); their positive tops have exponential shapes. An additional stage consisting of tube T_4 provides switching pulses of the shape shown in Fig. 2b.

Negative overshoots and distortion of pulses by the C_2R_1 and $C_{10}R_{15}$ circuits as well as by the imperfections of filters in the cathode and screen-grid circuits of tubes T_2 and T_3 lead to intolerably bad reproduction of switched low voltages. In practice, complete blocking of the 6Zh2P tubes (T_2T_3) occurs when a negative pulse $U_{blk} \geq 20$ v is impressed on the suppressor grids, provided the mutual conductance of the suppressor grid is $S_{s3} = 25\,\mu a/v$. Since $U_{in\,min} \geq 50$ mv, and the gain is $k = 20$, the output voltage will be $U_o \geq 50 \cdot 10^{-3} \cdot 20 = 1$ v. For the output switching interference not to exceed 5% of the minimum output signal, i.e., not to be greater than $\Delta U_o int = 1v \cdot 0.05 = 50$ mv, the interference voltage on the suppressor grids, i.e., the distortions of the negative pulse tops, must not exceed

$$-\Delta U_{sp} < \frac{\Delta U_o\,int}{S_{s3}R_4} = \frac{50 \cdot 10^{-3}}{25 \cdot 10^{-6} \cdot 4.7 \cdot 10^3} = 0.4\,v. \quad (1)$$

By means of similar reasoning it is possible to determine for a conducting tube with $S_{sc} = 0.7$ ma/v the permissible distortion of the positive switching-signal tops

$$+\Delta U_{sp} < \frac{\Delta U_o\,int}{S_{s.c.}R_4} = \frac{50 \cdot 10^{-3}}{0.7 \cdot 10^{-3} \cdot 4.7 \cdot 10^3} = 15\,mv \quad (2)$$

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Fig. 2

Negative overshoots of pulses on the anode of T_4 and subsequent distortions lead to immeasurably greater distortion of the switching pulses than the maximum permissible values determined by (1) and (2).

Diodes D_1 and D_2 which are fed with the blocking voltage of -20 v serve to cut off the negative overshoots. The pulse amplitude at the anode of T_4 amounts to 35 v and is limited across resistors R_2 and R_{17} by means of diodes D_1 and D_2 to -20 v with an error of ± 0.2 v.

The switching pulse distortions due to coupling circuits C_2R_3 and $C_{10}R_{15}$ and the imperfection of filters in the cathode and screen-grid circuits of tubes T_2 and T_3 are corrected by capacitor C_3 in the anode circuit of these tubes. It is known [1] that the distortions introduced by decoupling circuits are affected not only by the parameters of the circuits themselves but also by those of the tube di_a/dU_{g1}; di_s/dU_{g1} and di_s/dU_s; in view of the dispersion of the tube characteristics a specially selected set of spare tubes and a separate correction of each stage are required. Since the two stages have a common anode load, their correction is adjusted separately by selecting appropriate decoupling screen grid capacitors C_5 and C_6 (tubes T_2 and T_3). The relative value of the pulse top distortions due to the screen grid decoupling is [1]:

$$\beta = \frac{\Delta U}{U} = \frac{S_s}{C_s} t, \tag{3}$$

where ΔU is the absolute value of a "dip" or "overshoot" in the flat top of the pulse; $U = 20$ v is the amplitude of the pulse; $S_s = di_s/dU_s = 0.1$ ma/v is the screen-grid mutual conductance of the tube; $C_s = 30$ μf is the screen-grid decoupling capacity; $t = 0.01$ second is the duration of the pulse (the switching frequency is 50 cps).

Hence

$$d\beta = -\frac{S_s t}{C_s^2} dC_s$$

Since $\Delta \beta$ is small it is possible to assume that

$$\Delta \beta = \frac{\Delta U}{U} = \frac{S_s t}{C_s^2} \Delta C_s.$$

If the capacitance C_s is selected with an error of 0.5 μf we have:

$$\Delta U - US_s t \frac{\Delta C_s}{C_s^2} = 20_s \cdot 0.1 \cdot 10^{-3} \cdot 10^{-2} \sec \cdot \frac{0.5 \cdot 10^{-6}}{(30 \cdot 10^{-6})^2} = 11 \text{ mv} \tag{4}$$

which does not exceed the maximum permissible value of $+\Delta U_{sp\ int} = 15$ mv.

Fig. 3

715
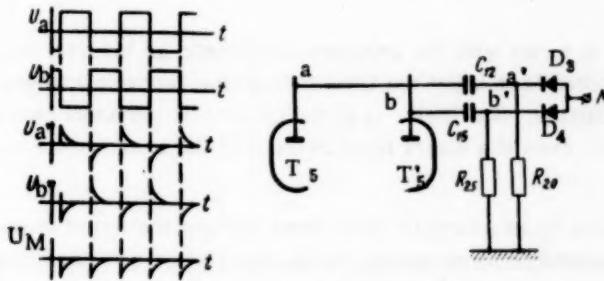
Switching pulses are fed from the anodes of T_5 through the differentiating circuits $C_{12}R_{20}$ and $C_{15}R_{25}$ to the diodes D_3 and D_4 (Fig. 3); from diodes D_3 and D_4 the negative pulse fronts appear at terminal M (Fig. 1) which is connected to the modulating electrode of the cathode-ray tube, and extinguish the beam during switching, thus ensuring a clear image of the switched signals.

The superposition of the curves on the screen of the cathode-ray tube is attained by adjusting the mean values of the anode voltages of tubes T_2 and T_3 by means of potentiometers R_1 and R_{10}.

The measures adopted for correcting the shape of switching pulses by means of diodes D_1 and D_2 and capacitors C_5, C_6, and C_7 have provided a considerable drop in interference and distortion occurring during switching (as it has already been pointed out the interference of the switching voltage referred to the input amounts to less than 5% of 50 mv of the input signal, i.e., to 2.5 mv), and ensured a practically distortion-free switching of input voltages with a minimum amplitude of 50 mv. Normal commutators will not switch without distortion such small voltages. For instance, the widely used electronic commutator ÉK-1 begins to distort the switched signals if their amplitude is smaller than 1500 mv.

Laboratory tests of the commutator which was working with input voltages of the order of 30 mv and over confirmed the conclusions arrived at in this article.

V. P. Ivanov participated in the construction and adjustment of this commutator.

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LOWERING OF THE BOTTOM LIMIT FOR MEASURING
INDUCTANCES BY A BRIDGE METHOD COMBINED
WITH SUBSTITUTION

G. Ya. Gurovich

The accuracy of measurement by the bridge method at audio frequencies drops rapidly when small inductances are measured or when the Q factor of the inductance is low.

In the practical application of bridges in this country the wide possibilities offered by a combination of the bridge and substitution methods are not fully utilized. The substitution method, however, with the use in this case of inductor boxes, provides a considerable extension of the bridge range for the lower inductance values. Moreover, the range of the bridge is also extended with respect to low Q factors, which is another equally valuable advantage of this method.

In fact, by connecting in series with the unknown inductance an inductor box, as shown in the block schematic attached, it becomes possible to bring the total inductance connected to the bridge terminals within the range of the bridge. In addition, the high Q factor of the box inductors provides a measurable Q-factor value for the total inductance, even if a direct measurement of the unknown inductance is impossible owing to its low Q factor.

Let us illustrate the above by an example taken from the application of universal bridge UM-2. The lowest inductance measurable by this bridge is, according to the description and operating instruction of the bridge, 100 μh (see also [1]). However, measurement of delay-line coil inductances (starting at 30μh), which were required by the specification, could not be carried out in a certain factory with a UM-2 bridge not only because the accuracy of measurements of such inductances could not be guaranteed on this bridge, but also because it
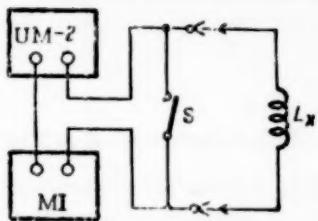
was impossible to obtain a zero balance on the "phase" dial of the bridge. Owing to the low Q factor of the delay line coils, it was even impossible to measure the total inductance of the line (of the order of 1 mh) which was also required by the specification.

The operation instructions of bridge UM-2 explain what to do if it is impossible to obtain a phase balance due to large values of the Q factor, but they do not make any recommendation for measuring coils with a low Q factor.

Eighteen months' experience in shop measurements of delay lines and other components has proved the technique, based on the use of the UM-2 bridge and a MI inductor box which were connected as shown in the schematic attached, to be satisfactory.

For measuring inductances of the order of 30-100 μh the box is connected in the circuit and set to an inductance of the order 1 mh ($9 \cdot 0.1 + 0.1$ on the variometer). Switch S is shorted. By rotating the "phase" and "value" dials of the bridge a minimum reading is obtained on the galvanometer. By opening switch S the unknown inductance L_x is connected in series with the box. By adjusting the variometer of the box and the "phase" dial of the bridge, balance is restored. The difference in the box readings gives the value of the unknown inductance. When measuring inductances of the order of 1 mh, other terminals of the box are used and it is set to 10 mh ($9 \cdot 1.0 + 9 \cdot 0.1 + 0.1$ on the variometer). Measurements are made in the same manner as previously. In both cases the minimum of the galvanometer reading is pronounced.

This method eliminates the error introduced by the bridge; neither does the residual inductance of the box have any effect on the measurements. The Kiev "Tochélectropribor" plant guarantees an accuracy of the MI variometer readings within ± 1 μh. With the corrections given in the certificates attached to the box, accuracy in measuring small inductances is, in fact, much greater. These statements also apply to bridge UM-3. The error in measuring small inductances by means of that bridge, amounting to $\pm(1 + 200/L_x)\%$, in many instances exceeds the permissible value. It is easy to see that if in our case the inductance, despite its low Q factor, could be measured directly on the UM-3 bridge, the error of measurement would have still been higher than with our method.

In extending the range of the bridge with respect to inductance with a low Q factor, this method provides a measurement of the inductance only but not of the Q factor.

Moreover, for inductances which are considerably smaller than the lower limit of the bridge, the above reasoning no longer holds. In certain cases the sensitivity of the null indicator incorporated in the bridge may prove decisive and determine the amount by which the bridge measurement can be extended.

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A PORTABLE ATTACHMENT FOR CHECKING TUBE VOLTMETERS

A. D. Taratenko

In order to simplify the checking of tube voltmeters at the commercial frequency, the Kuibyshev State Inspection Laboratory of Measuring Equipment developed a compact attachment, which consists of a potential divider with appropriate switching.

Its voltage ratios are equal to 10, 100, 1000.
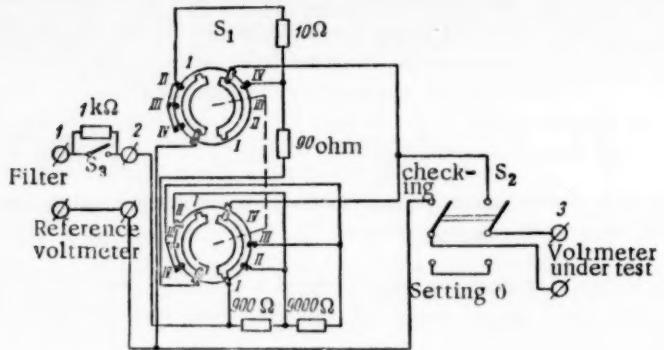
The attachment (see figure) consists of four nonreactive resistors of 9000, 900, 90 and 10 ohms, which form by means of switch S_1 in positions 2, 3, and 4 a potential divider with voltage ratios of 10, 100, and 1000. In position 1 of switch S_1 the voltage supplied to the reference voltmeter is fed to the voltmeter under test without attenuation.

An adjustable voltage is fed through a filter to terminals 1. A reference voltmeter type AMV or ASTV is connected to terminals 2. The voltmeter under test is connected to terminals 3. Switch S_2 serves to check the zero of the tube voltmeter before and during testing. Switch S_3 connects a 1 kilohm resistor when working with reference voltmeter type AMV.

The divider resistors have bifilar sectionalized and screened windings and are certified for an accuracy of ± 0.02%.

Auxiliary tables of tolerances for tube voltmeters type VKS-7, VLU-2, LV-9, MVL-1 and MVL-2 for checking with voltage ratios of 10, 100, and 1000 are given in instruction 210-54 of the Committee of Standards, Measures and Measuring Instruments (issue 1959).

This equipment increases the testers' productivity of labor on account of the decreased time in selecting voltage ratios and working out the test results.

A METHOD OF EXTENDING THE RANGE OF EMF MEASUREMENTS
BY DC POTENTIOMETERS

E. P. Maslov

At present dc potentiometers are being widely used in many spheres of electrical engineering. The high accuracy and stability of readings, the possibility of measuring emf's or voltages without distortion make these instruments irreplaceable in many instances.

The top limit of the potentiometer ranges seldom exceeds 2 v, which in many cases is not high enough.
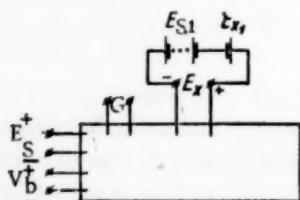
If a potential divider is used, the measured circuit is closed by a resistance, thus loosing one of the advantages of the compensation method.

Below we give a method of extending the top limit of a potentiometer range and at the same time preserving all the advantages of compensation.

It will be seen from the schematic (see figure) that in this method a standard cell (or a group of cells) E_{S1} is connected in series opposing the unknown emf E_{X1}.

Thus, the potentiometer terminals are fed with the difference of

$$E_{X1} - E_{S1} = E_X.$$

where E_{X1} is the unknown emf.

Naturally the number of standard cells is chosen to make the difference E_X smaller than the top measuring limit of the potentiometer.

E_X is measured in the normal manner, i.e., the measuring current is first calibrated against E_S and then E_X is measured. Moreover, the standard cell E_S can be used as E_{S1} for obtaining the difference E_X.

This method is essentially a differential one, since the potentiometer is used for measuring the difference between an unknown quantity and a standard measure whose value is known with great precision.

The use of the differential method raises considerably the accuracy of measurement as compared with that of the instrument itself. Another advantage of this method is the possibility of keeping the measuring current of the potentiometer low when measuring emf's; a high current in certain cases is highly undesirable.

This method can be used for measuring emf's of the order of several volts.

Although theoretically any extension of the potentiometer range is possible by this means, the connection of a large number of standard cells is undesirable.

MEASUREMENTS AT HIGH AND SUPERHIGH FREQUENCIES

THE LIMITING Q VALUES OF CRYSTAL RESONATORS

E. D. Novgorodov

One of the most important properties which determines the stability of crystal oscillators is the Q factor of their quartz resonators. That is why a lot of research is now being carried out with the aim of obtaining high Q quartz resonators. In this connection arises the question of the maximum Q factor which it is possible to obtain in quartz resonators.
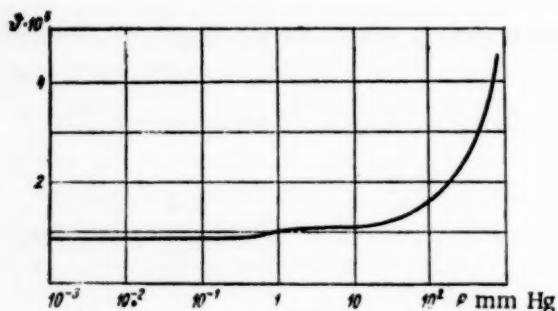
Fig. 1

It is common knowledge that the value of the Q factor is determined by the dissipation of oscillating resonator energy in the surrounding media, the holder, surface layer, and finally, in the crystal itself. By investigating the relations between all these energy losses it is possible to arrive at certain conclusions regarding the limiting Q factor of quartz resonators.

This article describes the results of research carried out at the Khar'kov State Institute of Measures and Measuring Instruments on the dissipation of energy in 100 kc quartz slices oscillating longitudinally (X axis) at the second overtone. The crystal slices were excited by means of electrodes with air gaps, thus eliminating energy losses in the metallized layers. The surfaces of all the slices had an optical-polish finish. For the sake of convenience, instead of the Q factor, its reciprocal, the damping ratio, was measured.

Tests of the relation between the damping ratio and ambient medium pressure (Fig. 1) showed that in order to avoid any appreciable effect of the latter on the former, it is sufficient to place the quartz slice in a container with a pressure in it maintained at about 10^{-3} mm Hg. Numerous tests have shown that at this pressure the medium increases the damping ratio only by a value of the order of 10^{-8}.

If the quartz slice is placed along its nodal lines on stretched silk threads, it becomes practically free of the effect of supports on its Q factor. This fact is demonstrated by the experimentally obtained curves of the relation of the damping factor to the distance of the threads from the nodal lines with threads of various thicknesses (Fig. 2). It will be seen from the curves that these relations are parabolic and can be expressed as

$$\vartheta = k \; l^2 + b.$$

Quantity b is the same for all the threads and represents the residual damping factor due to causes other than suspension. The factor k for thin thread (No. 50) is equal to $5 \cdot 10^{-7}$. The threads were placed at the nodal points with an accuracy of 0.3 mm. Hence the energy losses in them could not have increased the damping factor by more than $5 \cdot 10^{-8}$.

Thus the damping factor of slices which rest freely along their nodal lines on thin threads in an ambient pressure of the order of 10^{-3} mm Hg is due in the main to energy losses at the surface and inside the resonator, since the damping factor due to the energy losses in the threads and the medium is of the order of $5 \cdot 10^{-8}$, i.e., less than 1% of the total value of the damping factor.
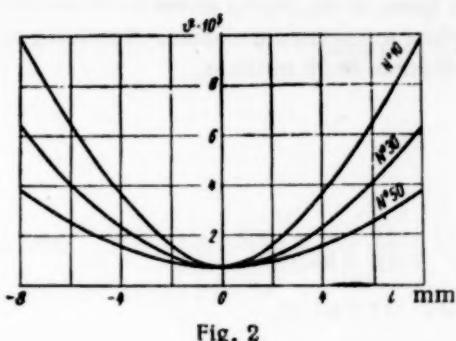
Fig. 2

Sample number	1	2	3	4	5	6	7	8	9
h, mm	13.6	13.6	6.8	6.8	4.5	4.5	3.0	3.0	2.0
Experimental $\vartheta \cdot 10^6$	3.3	3.4	6.8	6.7	10.2	9.7	14.6	15.1	22.2
Calculated $\vartheta \cdot 10^6$	3.3±0.1		6.6±0.2		9.9±0.2		14.8±0.2		22.1±0.3

In order to determine the relation between the surface and bulk losses, L. D. Bryzzhev suggested measuring the effect of the surface to volume ratio of the slice on its damping factor. For this purpose damping factors of slices with varying thicknesses $\underline{h}$ (see table) were measured.

The damping factor was determined by the width of the resonance curve. The probable error of a series of 10 measurements was estimated at 1%.

It is known that the damping factor is represented by the formula:

$$\vartheta = \frac{\Delta W}{W},$$

where W is the total energy of oscillations proportional to the stressed volume, in the case of the slice to its entire volume V, i.e., $W = k_1 V$; and ΔW is the energy loss during half a cycle, consisting of the surface losses ΔW_s and bulk losses ΔW_b. Obviously ΔW_s is proportional to the stressed side surface S of the slice and ΔW_b is proportional to its volume V, i.e., $\Delta W_S = k_2 S$; $\Delta W_b = k_3 V$. Hence

$$\vartheta = \frac{k_2 S + k_3 V}{k_1 V} = A \cdot \frac{S}{V} + B,$$

where A and B are constant coefficients.

Thus the damping factor consists of two parts: one part B is determined by the volume losses and does not depend on the dimensions of the slice, the other part is determined by the surface losses and is proportional to the relation of the side surface to the volume of the slice. Since this relation in the slice is equal to 4/h (h is is the thickness of the slice) we have

$$\vartheta = A \frac{4}{h} + B. \tag{1}$$

If the values of ϑ and $\underline{h}$ given in given in the table are substituted in (1) we shall obtain a system of simultaneous equations from which A and B can be determined. Without giving the method of solution we shall only quote the result

$$A = (11.0 \pm 0.1) \cdot 10^{-6}; \quad B = (0.1 \pm 0.1) \cdot 10^{-6}$$

Hence according to (1)

$$\vartheta \cdot 10^6 = \frac{4}{h}(11.0 \pm 0.1) + (0.1 \pm 0.1), \tag{2}$$

where thickness $\underline{h}$ of the slice is taken in millimeters.

The experimental values of the damping factor agree well with those calculated from formula (2) and given in the last line of the table. Quantity B which gives the internal losses in the crystal serves to determine the minimum to which the damping factor can be decreased, if the surface losses are eliminated. According to the above data this minimum amounts to $2 \cdot 10^{-7}$ which is equivalent to a Q factor of 15 millions.

MEASUREMENT OF THE CARRIER FREQUENCY OF THE RB-79
RADIO STATION BY MEANS OF THE HETERODYNE METHOD
USING A KG-B CRYSTAL OSCILLATOR

V. P. Kitavin

Strict tolerances have now been established for deviations of carrier frequencies from those allocated to radio stations. This tolerance amounts to $\pm 0.003\%$ and even less. In order to assist the Murmansk broadcasting station, which has no measuring equipment capable of checking the station's carrier frequency, we measured the frequency of station RB-79 by a heterodyne method with the required accuracy, and we can continuously control the frequency.

The measurements are made in the following manner: the frequency allocated to station RB-79 is 656 kc, with a permissible deviation of ± 10 cps.

A receiver tuned to 656 kc is fed with the 66th harmonic of a quartz crystal oscillator type KG-B. A difference frequency of the order of 4000 cps is heard at the output of the receiver, which is operating in a telephone connection. Since the frequency under test is modulated by the broadcasting program, this program will also be audible at the receiver output; in order to decrease its volume the receiver should be slightly detuned to about 658 kc.

The difference frequency is measured on set UCh-2. The actual value of the station frequency is $l_x =$ $= 660,000 - F$, where F is the difference frequency in cps as measured on set UCh-2.

The frequency of the quartz oscillator is checked against the 200 kc standard carrier frequency of station RV-71 and is adjusted so that its error at the 10 kc output does not exceed ± 0.03 cps, and hence at the frequency of the 66th harmonic ± 2 cps.

The error of measuring the difference frequency on the UCh-2 set does not exceed $\pm 0.03\%$.

The absolute error is

$$\Delta F = \pm \frac{4000 \cdot 0.03}{100} = \pm 1.2 \text{ cps.}$$

The root-mean-square error of checking is

$$\gamma = \pm \sqrt{2^2 + 1.2^2} \simeq \pm 2.5 \text{ cps.}$$

The relative error of checking amounts to

$$\Delta \gamma_0 = \pm \frac{2.5 \cdot 100}{656000} \simeq \pm 0.0004\%.$$

This method ensures a reliable control of the tolerance of the carrier frequency and can be used for measuring carrier frequencies of other radio stations, provided the difference between their frequencies and that of the quartz oscillator (or its harmonics) does not exceed the bandwidth of the receiver used.

OPTICAL MEASUREMENTS

CHECKING THE FLATNESS OF MICROMIRRORS BY THE INTERFERENCE METHOD

L. D. Drozdova

The checking of micromirrors smaller than $1 \times 0.8 \times 0.5$ mm, used in sensitive elements of recording instruments, is made difficult by the strict tolerances imposed on their flatness. Thus, the mirror flatness must be of the order of 0.1-0.2 of the interference fringes measured.

Our industry does not produce any instruments for checking the flatness of mirrors.

Fig. 1

For this purpose we used a biological microscope MA whose objective was replaced by a special attachment of the type of an IZK-46 interferometer, and a special rocking holder was mounted in the hole of the microscope stage.

Fig. 1 shows the optical diagram of the instrument. Electrical bulb 1 throws a beam of light on glass cube, 2, which is made of two rectangular prisms one of which has its hypotenuse face covered with a semitransparent layer of aluminum.

Cube 2 divides the beam into two coherent parts. One beam passes through the cube and falls onto flat mirror, 3, which is covered by an external layer of aluminum and is placed at right angles to the axis of the incident beam of light. Having been reflected from mirror 3, the beam returns to cube, 2, and, reflected from its semitransparent diagonal, passes through objective, 4, to the microscope eyepiece 5.

The second beam is reflected downwards from the semitransparent cube 2 diagonal and strikes the face of micromirror, 6, which is being tested; having been reflected from the micromirror the beam passes through cube, 2, objective, 4, and reaches eyepiece, 5, where it produces interference with the first beam.

The interference picture is examined through eyepiece 5.

The special rocking table, 1, mounted on spring support, 2, with two adjusting screws, 3 (Fig. 2) is the novel feature of the instrument.

By means of the adjusting springs the plane of the table is set at an angle to the microscope optical axis, which produces distances of 3-6 mm between the adjacent interference fringes as seen in the eyepiece of the microscope. Such an expansion of the fringes provides the possibility of determining mirror irregularities in fractions of a fringe.

Interference fringes also reveal mechanical damage of the mirror reflecting layer (scratches, chips, etc.).

The mirror under test is placed in position by means of a rod shaped like a screwdriver, whose end is dipped in alcohol or pure benzine in order to make the mirror stick to the rod. The aluminum covered surface of the micromirror is found by viewing it at an angle, then the mirror is placed with this side uppermost onto a polished plate (better still a lapped face of a block gage of 7-10 mm) so as to make the handling of the mirror under the objective more convenient by displacing with one's fingers the gage with the mirror instead of the mirror alone.
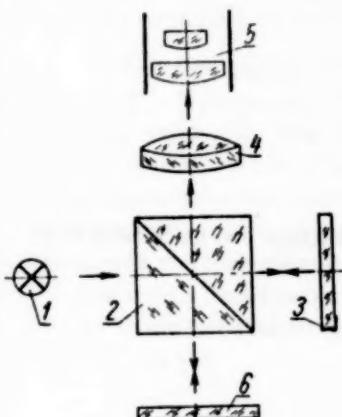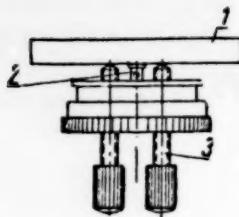
Fig. 2
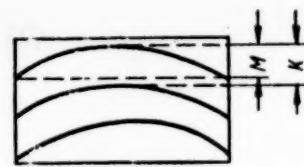
Fig. 3

If the face of the micromirror is flat the interference fringes will be straight.

If the mirror surface is concave, convex, or irregular, the interference fringes will be distorted either locally or generally (Fig. 3).

The distance between the interference fringes corresponds to half a light wavelength, 1/2 λ.

In order to determine the amount of mirror deviation from flatness, it is necessary to find the ratio of distortion M of the fringe and the fringe spacing K (Fig. 3) and multiply it by 1/2 λ.

Hence the deviation from flatness M can be represented by

$$N = \frac{M}{K} \cdot \frac{\lambda}{2}.$$

In white light λ = 0.55 μ hence:

$$N = \frac{M}{K} \cdot 0.275 \, \mu$$

Measurements are made by inspection and, with practice, deviations of 0.1 of a fringe can be reliably estimated.

METHODS OF CHECKING ELECTRICITY METERS

A. M. Ilyukovich

All the methods of checking electricity meters can be divided into two groups: those which use a wattmeter or a comparator as a standard instrument for measuring the ac power, and those which employ a standard electricity meter.

Wattmeter Methods

The Wattmeter-Stop Watch Method. The main defect of this method consists in the inaccurate maintenance of a constant load by manual adjustment, when normal stop watches and grade 0.2-0.5 wattmeters are used.

A desire to improve this method and raise its accuracy led to the use of automatic revolution counters (Fig. 1) [1]. A photorelay, 2, consisting of an illuminator and a photoelement is placed immediately in front of the meter under test. The light beam is reflected from the meter disk and falls on the photoelement. Every time the dark spot on the rim of the disk passes in front of the meter viewing window the beam is attenuated, producing an electrical pulse, which is fed through amplifier, 3, to computer, 4. On receiving the first pulse, the computer connects a time measuring device, 5 (for instance, a chronograph), counts off a preset number of pulses and disconnects the time-measuring device. For the production of pulses, bevelled disk edges are often used instead of the dark spots. This arrangement provides a more reliable operation of the pulse generator, especially in the case of an enclosed meter [2, 3]. Attempts are being made to use radio isotope transducers for producing the required pulses [4].

Fig. 1

To a dc potentiometer
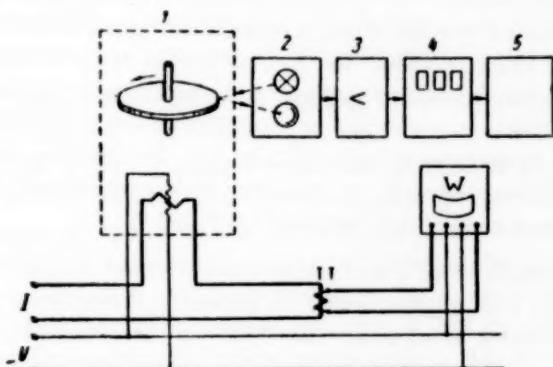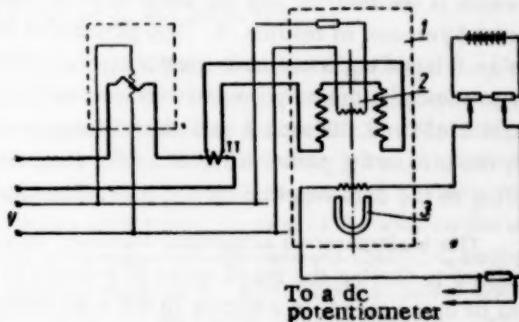
Fig. 2

The Wattmeter-Timer Method. In this method, meter readings are taken over a definite, accurately preset time interval. The timer consists of a system of contacts and telephone relays, controlled by a synchronous motor, fed from a tuning-fork oscillator. The timer switches on and off the meter supply over a strictly definite time interval, for instance, 90 seconds. The operator only has to read the meter after the lapse of this interval of time. The use of timers is only possible when checking portable meters with a scale which reads in hundredths of a meter disk revolution and has a device for returning the pointers to zero. This method of checking meters is used by the All-Union Scientific Research Institute Committee of Standards, Measures, and Measuring Instruments as well
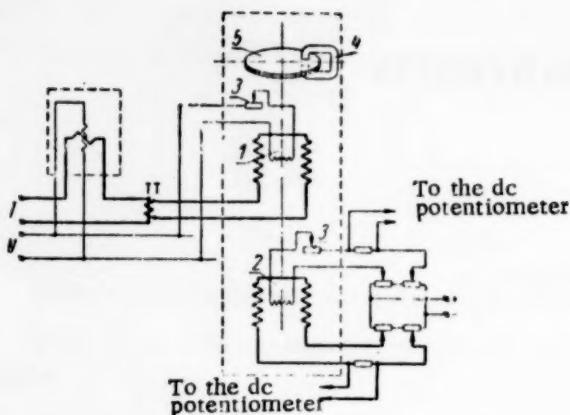
Fig. 3
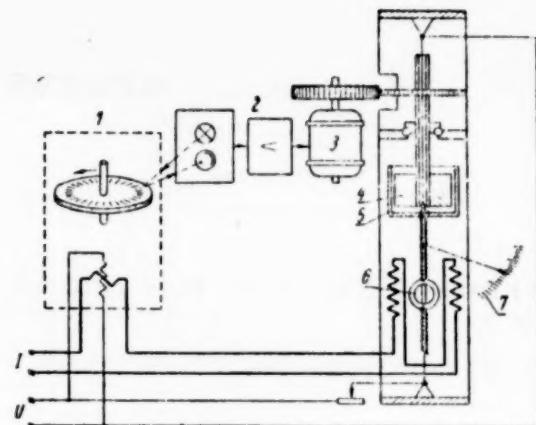
Fig. 4

as abroad [8]. With the wattmeter-timer method it is possible to measure several meters at a time, which cannot be done with the wattmeter-stop watch method.

Comparators for Measuring AC Power. In order to increase the accuracy of meter checking, instead of the ordinary dynamometer wattmeters, comparators which, according to the firm's data, can measure ac power with an accuracy of 0.03-0.05% are used. Comparator 1 (Fig. 2) consists of electrodynamic, 2, and magnetoelectric, 3, measuring elements, connected so that their torques are in opposition. When the comparator is adjusted all three windings are connected in series and fed by a direct current which is controlled with a potentiometer. By means of regulating devices a complete balance of the torques of the two measuring elements is attained. Then the comparator constant is determined, which equals the ratio of the power in the dynamometer to the current through the moving coil in a balanced condition of the instrument. When measurements are made with the circuit shown in Fig. 2, a balance is obtained and the direct current flowing through the moving coil determined by means of a dc potentiometer. The ac power is determined from the value of the measured dc current and the comparator constant.

AC-DC"Balance of Work" Method. The use of a wattmeter or a comparator requires accurate stabilization of the ac supply. This, however, is a complicated matter. The SSW company (FGR) was able to avoid the necessity of supply stabilization by using the so called ac-dc balance-of-work method of measuring [9]. This method (Fig. 3) consists of using two electrodynamic measuring instruments 1 and 2 connected with opposing torques, one of which is fed from dc and the other from ac supplies. The calibration of the instrument is carried out on direct current by means of resistor 3. The permanent magnet 4, which operates disk 5, converts the power comparator into an integrating instrument measuring the difference of the dc and ac energies. It is, therefore, no longer necessary to maintain the ac power strictly constant, and it is sufficient to obtain a zero reading on the instrument over a period of time. In such a case the difference of ac and dc energies is equal to zero, i.e., the mean ac power over the measuring period is equal to the dc power, which is measured by means of two dc potentiometers. According to the data supplied by the firm, the error of measurement of this instrument is 0.04% [9].

The Wattmeter—Tachometer Method. In all the methods so far described the essence of the measurement consisted in finding the mean speed of rotation of the meter with a given load. For measuring instantaneous instead of mean speed, in addition to the wattmeter, it is necessary to have, instead of the stop watch or chronograph, a standard tachometer. Such a method is used in B. Ya. Romanikhin's [10] device which automatically compares the speed of rotation of the meter with the power applied to it (Fig. 4).

The specially graduated disk of meter, 1, under test is illuminated by a beam of light. The light reflected from the disk and received by the photoelement varies proportionately to the speed of the disk. The output of the photoelement is connected to amplifier 2, which supplies a synchronous motor, 3. The speed of the motor is proportional to that of the meter disk. The motor drives through a geared connection and induction tachometer; which consists of permanent magnet, 4, and a shell, 5, made of conducting material. The torque acting on the shell is proportional to the speed of rotation of the magnet, i.e., to the speed of the meter disk. Moving coil, 6, of a dynamometer wattmeter is fixed on the same axle as the shell and the wattmeter is connected to

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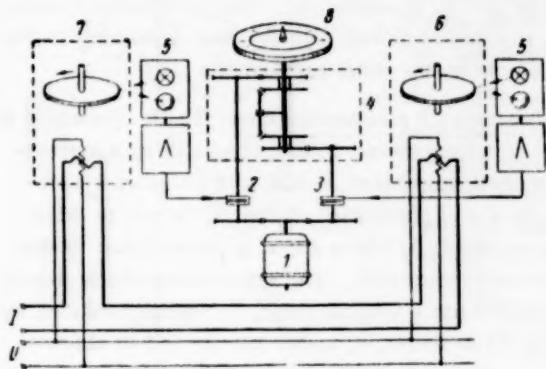
Fig. 5
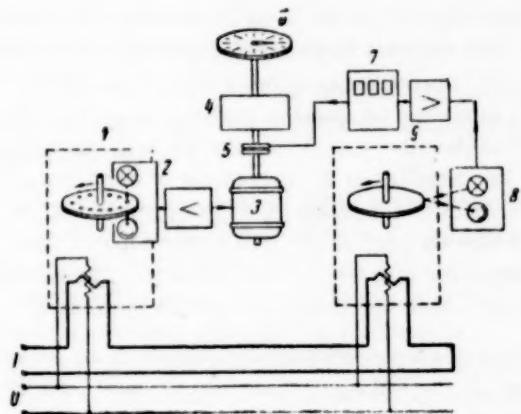
Fig. 6

the same circuit as the meter under test. The torque of this wattmeter is proportional to the load and is connected in opposition to the torque of the tachometer shell. Scale 7 indicates the error of the meter. By means of this instrument, according to [10] great accuracy is attained in checking electricity meters, and its main purpose is the checking of standard meters. A disadvantage of this instrument is its instability if the electricity meter under test has periodic variations of speed within one revolution of the disk.

The checking of meters by means of the watt-meter — tachometer method can also be carried out in a simpler manner. Thus, it is sufficient to measure the speed of rotation of the electricity meter by stroboscopic means while the power in the circuit as read on a wattmeter is maintained constant [11]. This method, however, similarly to those previously examined, requires a stabilized power supply. At present there is only one instance when it is employed, namely when checking electricity meters which are being adjusted at a constant load [12].

Method Employing Standard Electricity Meters.

The checking of the standard electricity meters themselves can only be carried out by means of watt-meter or other power-measuring devices.

Checking of individual electricity meters by means of standard meters is well known.

Automation of Individual Checking. In starting and stopping a standard electricity meter subjective errors are inevitable. In order to avoid them, the previously mentioned automatic counting of disk revolutions of the meter under test is employed. The measuring circuit in the latter case only differs from the one shown in Fig. 1 by the computer switching off the voltage of the standard meter instead of the timer [13].

Two other circuits for checking meters by means of standard meters [1] are shown in Figs. 5 and 6. In the circuit shown in Fig. 1 a small synchronous motor 1 operates a differential drive 4 by means of electromagnetic clutches, 2 and 3. These clutches are operated by photorelays 5 placed in front of the meter 6 under test and the standard meter, 7, and energized when the dark spots pass in front of the photoelement. When the device is switched on, and as soon as the dark spot on the disk of the meter under test passes in front of the photoelement, clutch, 3, operates and pointer, 8, is driven by the synchronous motor to the left. As soon as the spot on the disk of the standard meter passes in front of the photoelement, clutch 2 is operated, synchronous motor, 1, begins to drive both sides of the differential gear, 4, and the pointer, 8, remains stationary. When the spot passes again in front of the element of the meter under test, clutch 3 is disconnected and the motor drives pointer 8 through clutch, 2, to the right until the spot of the standard meter passes in front of its photoelement and disconnects clutch, 2. The final position of the pointer is proportional to the difference in time between a complete revolution of the meter under test and the standard meter.

In the circuit of Fig. 6, standard meter, 1, has a disk with a large number of evenly space holes. Photoelement, 2, produces, as the result of modulation by the beam of light which passes through the holes, an alternating current, whose frequency is proportional to the speed of rotation of the standard meter disk. Synchronous motor, 3, rotates pointer, 6, through a continuously variable drive, 4, and an electromagnetic clutch, 5. The scale indicates the percentage error of the meter under test. The electromagnetic clutch, 5, is controlled by computer,

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Fig. 7

Fig. 8

7, which is operated by the photorelay, 8, actuated by the disk spot of meter, 9, under test. The continuous variable drive, 4, is adjusted before measurement according to the constant of the meter under test and the load.

A device with a recording chart [14] is illustrated in Fig. 7. A standard meter, 1, has, similarly to the previously described instrument, a disk with holes which produces by means of photorelay, 2, an ac current to drive synchronous motor, 3, whose speed is proportional to that of the standard meter disk. The synchronous motor drives drum, 4, which has a helical ridge, 5. Pulses produced by photorelay, 7, of meter, 6, under test are fed to electromagnet 8, which pulls down armature, 9, at each pulse thus pressing inking tape, 10, and the uniformly moving paper strip, 11, against drum, 4. The helical ridge, 5, marks paper strip, 11, at the point of contact. The speed of motor, 3, is selected to produce one revolution of drum, 4, during the interval between two pulses of the meter under test, providing its speed is correct. In such a case the row of consecutive marks on strip, 11, will represent a straight line parallel to the movement of the paper. If the matter under test is faulty, the row of marks will be drawn in a line inclined to the axis of the paper. The angle between the line and the axis measures the error of the meter; it is read by means of a special protractor.

Spot or synchronized movement methods are widely used for checking electricity meters. There exist equipment in which the setting of spots into the zero position and the switching in and out of the meters is either partially or completely automatic. The semiautomatic spot method is used among other places in the Moscow "Elektroschetchik" plant and the Mytishchi electricity meter plant for adjusting meters at small loads.

The checking cycle method is a variation of the synchronous method. The standard meter in this case is arranged to produce at each revolution a visual or an audio signal. During testing, the operator observes the coincidence of this signal with the passage of the spot on the disk of the meter under test behind some stationary detail. The main use of this method consists in a rough check of the meters during preliminary adjustments.

Control equipment method. In mass production of electricity meters their checking is done by means of computers.

The AEG company (FGR) [15] has introduced partly automatic operation of their control equipment by means of a dosimeter. The device consists of a combination of a standard meter with an instrument similar to the one used for counting the turns in the wattmeter stop-watch method.

By means of the dosimeter the electricity meters are switched off as soon as a given number of turns has been completed by the standard meter. This arrangement facilitates the work of the testing personnel, and provides the possibility of utilizing night time for checking meters on small loads.

Automatic Test Equipment. In recent years a considerable amount of work has been done in the USSR for making the testing of meters automatic. As the result of it, several devices have been constructed [2, 3, 16, and 17] which greatly increase labor productivity and accuracy and reliability of testing.

In the semiautomatic equipment of the Moscow Electromechanical plant [3], designed for testing three-phase electricity meters, a photoelectric transducer is placed in front of each of the 30 simultaneously tested meters. The disks of all the meters have bevels evenly distributed over their circumferences. The electrical pulses produced in the photocells when the disk rotates are amplified and fed to a mechanical pulse counter. The pulse counting circuit is automatically connected by a pulse from the standard meter when the equipment is switched

on and disconnected automatically when the disk of the standard meter has completed a predetermined number of revolutions. At the end of the test cycle, the operator determines the errors of the meters by the readings of the counters attached to each meter.

The equipment of the Moscow "Elektroschetchik" plant [17] automatically checks the meters at all the required loads. The operator has only to connect the meters to the test equipment and disconnect them after they have been automatically checked at all the required loads. This equipment is based on the principle of counting the number of pulses received from the standard meter during a given number of revolutions of the meter under test.

The same principle is used in the installation of the Vilnius plant of electricity meters [2] and the Leningrad Electromechanical plant [16].

Fig. 9

Stroboscopic methods of checking are used in mass production of meters [12, 18, and 19].

A beam of light is passed through a hole in the standard meter disk and directed onto a photoelectric transducer. The photocell's current has a frequency proportional to the speed of the disk's rotation and serves to feed a gas discharge lamp, which illuminates one or several meters under test.

The advantages of the stroboscopic method include its simplicity and high accuracy, but it cannot be used at small loads when the periodic variations of the disk speeds within one revolution of the meters under test become apparent.

Optical Compensator [20]. In this arrangement the ac current at the output of the amplifier, instead of feeding an illuminating lamp, supplies a synchronous motor, whose speed of rotation is proportional to that of the standard meter disk rotation. The axle of the synchronous motor carries an optical compensator, which consists of a plane-parallel plate placed in the path of the beam which is reflected from the graduation lines on the disk of the meter under test. From the optical compensator the beam is directed onto a frosted screen which is observed by the operator. The principle of operation of the compensator is shown in Fig. 8. If the compensator plate is revolving in the direction indicated by an arrow in the drawing, the operator will see on the screen a stationary row of graduations. In fact, let a graduation on the disk of the meter under test occupy at some instant position I, and let it correspond to position I on the plate. After a while the graduation will move to position II, but the operator will still see it in the same position, since the plate has also moved by a corresponding amount, etc. This, of course, is only true for small angles of rotation of the plate; that is why the optical compensator is made of two mutually perpendicular plates (Fig. 9) equipped with screens. The optical compensator produces a much sharper stroboscopic picture than the other method and makes observation more convenient.

The Use of a Cathode-Ray Tube as an Indicator. Satisfactory results are also obtained when a cathode-ray tube is used as an indicator of the equality of speeds of the standard meter and the meter under test [15, 21]. In one of the arrangements of that type [22] a stationary spot appears on the tube screen when the speeds are equal; if they become unequal, the spot moves along the screen in a horizontal direction with a speed proportional to the difference of the velocities of the standard meter and the meter under test. The accuracy in comparing the two speeds with cathode-ray tubes exceeds 0.1%. Methods of this type as well as the stroboscopic ones are used for checking meters with a nominal load.

Checking Three-Phase Meters.

The checking of three-phase meters has a number of peculiarities which it is necessary to examine.

The Wattmeter — Stop Watch Method. With an unstabilized supply the accuracy of checking three-phase meters is lower than that of single phase meters [7]. This problem is solved by using instruments which provide an accurate symmetry of phases in a three-phase circuit [1, 5] which permit one to check the power by means of one standard instrument.

The Standard Three-Phase Meter Method. Standard three-phase meters are less accurate than standard single-phase meters. This is due to the difficulties mentioned of checking three-phase meters. Sometimes three-phase meters are checked by means of several single-phase meters, which have been previously checked by other more precise methods. In this case the three-phase meters are also less accurate than single phase meters.
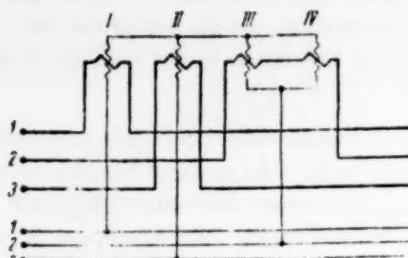
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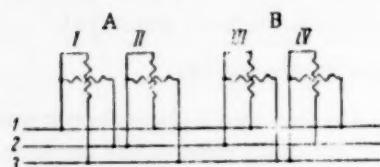
Fig. 11

Checking by Means of Single-Phase Standard Meters. Before the Second World War, attempts were made to use this method for mass-production checking, the readings of the single-phase meters being summed up by means of a mechanical device. The need to use this rather complicated device is a serious defect which prevented the checking of three-phase meters by means of single-phase ones from becoming widespread.

Three-Phase Current "Balance of Work". The SSW company (FGR) checks three-phase electricity meters against one single-phase meter. For this purpose it uses the so-called balance-of-work method [23]. The three-phase "balance of work" apparatus consists of a four-element induction instrument, which is connected to the measuring circuit as shown in Fig. 10. All the four elements have completely equal torques and drive a common moving part, moreover, the torques of elements I and II are connected in opposition to those of elements III and IV. When the sum of the powers in phases 1 and 3 is equal to double the power in phase 2, and hence the total power is equal to treble that of phase 2, the torques operating the moving part of the instrument are completely balanced and the part itself remains stationary. It is then only necessary to measure the power by means of a single-phase standard meter in phase 2 and treble it in order to determine the total energy in the three-phase circuit. The three phase "balance of work" device is an integrating instrument, and it is therefore unnecessary to keep its moving part stationary throughout the measuring time; it is sufficient to adjust the power in one of the phases in order to make the "balance of work" device indicate zero at the end of the tests. This will indicate that the energy dissipated in the three-phase circuit during the test period is exactly three times larger than the energy recorded by the single-phase meter.

Voltage Equalization when Checking Wattless Power Meters. The measuring mechanisms of certain types of wattless power meters, including those with a 60° and 180° internal phase displacement, are connected for checking to other voltages of the three-phase circuit than the corresponding measuring mechanisms of the standard instruments, for instance of ordinary wattmeters. If the triangle of line voltage is asymmetrical, the above circumstance may lead to inaccurate measurement. In order to make the voltage triangle symmetrical during the checking of the wattless power meters, the SSW company uses the so-called voltage symmetry indicator [24], whose schematic is shown in Fig. 11. This instrument consists of two double element induction devices mounted in a common body. In each element a torque proportional to two line voltages is induced. The torques of elements I and II which operate a common moving part are in opposition, similar to the torques of elements III and IV. A balance of the two moving parts indicates complete symmetry of the line measurements triangle. The indicator is an integrating instrument, i.e., it is only necessary to make both moving parts of the indicator return at the end of the test to the position they occupied at the beginning of the test. This will indicate that during testing the voltage triangle was "on an average" symmetrical. The indicator provides the possibility of maintaining voltage symmetry with an accuracy of 0.1%, which is sufficient to eliminate the effect of symmetry on the checking of wattless electricity meters.

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MATERIAL RECEIVED BY THE EDITORIAL BOARD

NOT PALTRY, BUT FUNDAMENTAL PROBLEMS

A. G. Ivanov

In his article entitled, "Certain problems of organization and activity of industrial test laboratories"* K. N. Katsman touched upon a question which cannot be disregarded by metrologists or metrological organizations. Unfortunately the title of the article makes the problem look less acute than it really is. Indeed the article asserts that many industrial test laboratories have recently stopped performing their basic functions and become merely test agencies.

At present when our industrial workers are mastering, in response to the decisions of the 21st Party Congress and the June Plenum of the CPSU Central Committee, the production of many new types of articles, numerous problems arise in developing modern measurement methods.

Increasingly accurate measurements are now required.

Who should deal with these questions in a factory ? In the first place, the industrial test laboratory, which should include in its personnel a highly skilled group for developing new measuring methods. This group should develop and test out the new methods.

According to the published industrial test laboratory regulations, such a group should exist, but in fact it is either lacking or if it does exist, it often fails to perform its proper functions.

It is impossible to disagree with the following propositions made in the article under consideration:

1. Industrial Test Laboratories have become purely factory inspection agencies, thus failing to assist in the improvement of measurement techniques.

2. Industrial Test Laboratories should guarantee the accuracy of technical test results, improving in every way the techniques involved by developing accurate and more productive methods of measurement. This function is not fulfilled by the majority of the ITL.

3. It is necessary to develop new specialized measuring techniques for each factory, thus effecting considerable saving by more accurate and speedy inspection and freeing, in many cases, expensive universal measuring instruments. Often, for instance, factories carry out precision measurements on special measuring devices, freeing the universal microscope for other work.

4. Industrial Test Laboratories should be able to compile competent requirements for the development of new types of instruments and insist on their manufacture and trial .

5. The rising technical level of all measurements and their interdependence make it desirable to combine all the test laboratories into a single Central Factory Test Laboratory (TsZIL) which would be engaged in all types of measurements: linear, electrical, thermotechnical, etc.

6. Central Factory Test Laboratories should be subordinated only to the chief engineer, and not the Technical Inspection Department. Often, owing to the fact that the Industrial Test Laboratories are subordinated to the Technical Inspection Departments, they cannot develop new methods of measurements or carry out investigations, since at the end of the month or quarter the latter department may allocate the laboratory workers to factory production inspection. There are instances where before the investigation has been completed, the article is put into use. The question of the quality of production is thus pushed into the background.

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* Izmeritel'naya Tekhnika No. 4 (1959). [See English translation]

The lack of trained personnel in the Industrial Test Laboratories was bound to have as its effect the loss of proper functions by the laboratories.

The Committee of Standards, Measures,and Measuring Instruments should organize in Moscow, Leningrad, and other administrative and industrial centers conferences of the heads of Industrial Test Laboratories in order to discuss the question of the present-day tasks of the laboratories.

The question of test schedules should also be examined.

In the factories,test schedules have lost their significance as metrological instructions and have become formal documents required by the factories for obtaining the Committee's permission to carry out measurements. The schedules are compiled in a simplified manner and the questions of production inspection are described in them formally and without clarity.

The very method of presenting the schedule in the form of a chart is at the present outdated and unsuitable, owing to the great expansion in the variety of measuring arrangements. The test schedules should be worked out separately and with greater care for various types of measurements such as linear, angle,and other measurements.

The work of the test laboratories is hindered by the inadequate supply of informative material on inspection methods.

Test laboratories use as their basic information material the collection of instruction entitled "Control of dimensions measuring equipment in engineering", whose second edition was printed in 1948. Since then the Committee has introduced many modifications and practically all the instructions comprising this collection have been revised, and many new instructions issued. It is difficult to obtain many of the new instructions since they have been issued in small numbers. It is therefore urgently necessary to issue a third edition of the collection of instructions.

The problems of improving the work of the Industrial Test Laboratories is of great importance and it should be tackled without delay.

A PLEA FOR EXTENDING THE RIGHTS AND DUTIES OF
THE INDUSTRIAL TEST LABORATORIES

M. I. Malakov

Technical progress depends on advanced technology expanding in industry, on wide mechanization and automation of production; it inevitably requires the development of measurement techniques and at the same time the enhancement of the role of industrial laboratories.

K. N. Katsman * is justified in criticizing many of the test laboratories for failing to lead the movement in industry aimed at implanting new technology, new inspection and testing methods, etc., and being completely absorbed in service inspection of the measuring equipment which already exists in the establishments.

In order to improve the efficiency of the factory testing department the Tambov "Komsomolets" plant amalgamated its measuring and mechanical laboratories.

The workers of our laboratory periodically check all the universal and fixed gages. We obtained from the Tombov State Inspection Laboratory of Measuring Technique the right to check by ourselves most of the universal measuring equipment without submitting it for state inspection, which will save the plant some 10 000 rubles per year. Moreover, the workers of our test laboratory periodically check all the production equipment. which affects

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* Izmeritel'naya Tekhnika No. 4 (1959). [See English translation.]

the quality of production. They take an active part in introducing new inspection methods, new testing techniques, etc. Thus, a complicated instrument, a helium leak detector PTI-4A, has been mastered by our laboratory workers.

Until quite recently the testing of vacuum and freon equipment was a weak spot in our factory. The plant produced the equipment, but all the testing had to be done at a high cost in Moscow, since we lacked the special testing instruments. With the direct assistance of the test laboratory workers we organized this type of testing and are now carrying it out in our own plant.

The elimination and prevention of scrap is another equally important activity of the test laboratory.

In the manufacture of a certain type of equipment, a large number of special helical extension springs was required. All these springs were checked in the test laboratory. As soon as the first batch of springs was made and tested, it was found that they were unsatisfactory. The second batch also had to be scrapped. Planned production of this equipment was on the verge of collapsing. We developed and applied a new technique which is still being used for the production of these springs. Scrapping was eliminated and the order fulfilled on time. This example is not exceptional.

The workers of the test laboratory assist and advise the gages and attachments design office of the engineering department in developing various measuring templets, combined gages, etc.

Despite the good stock of instruments in our possession, we ourselves have to develop the required instruments and attachments for carrying out certain measurements: a device for lapping micrometer faces, an instrument for determining the profile angle of thread gages, an attachment for measuring springs on a TK hardness gage, a universal attachment for measuring taper gages, and many others.

K. N. Katsman suggests quite correctly that the test laboratories should be subordinated to the chief engineer instead of the Technical Inspection Department. The workers in test laboratories, in the eyes of the Technical Inspection Department serve only to eliminate bottlenecks in production. We, for instance, replace inspection foremen, in case of their absence, in the mechanical and instrument shops, the department of the chief mechanic, etc. Moreover, as chief of the test laboratory I have to inspect personally the production and models made in the chief power engineer's department workshop. This requires a considerable amount of time, which could be better spent in providing unified measurements, introducing new methods of inspection, etc.

In conclusion I should like to mention the relation between the Tombov State Inspection Laboratory of Measuring Technique and the test laboratories. Despite the fact that our laboratory is well thought of by the State Inspection Laboratory (we were first in the region to be given the right to inspect our universal gages ourselves without submitting them for state inspection) we have no close business relation with them.

The State Inspection Laboratory sends its workers to the plant only for general inspections or investigations. It would be desirable for the State Inspection Laboratory representative, when he comes to the plant, not only to inspect, but be able and willing to help us with advice and assistance.

IMPROVEMENT IN THE SUPPLY OF MEASURING AND
TEST EQUIPMENT

I. D. Shamin

In recent years many establishments have received the right to perform by themselves the compulsory checking of their measuring equipment, including opticomechanical instruments. The instructions specify certain equipment for checking these instruments, but centralized production of some of the equipment has not been organized. The recommendations contained in various instructions and specifications on the maintenance of measures and measuring instruments remain on paper only.

Thus, according to instruction 106-56 a 1st grade standard glass scale 200 mm long and a special templet rule are required for checking universal microscopes. These instruments are made in Leningrad, but they are lacking in all laboratories, including base laboratories.

For checking microscopes, standard scales made in Balashikha and Kiev are required, but it is very difficult to obtain them since they are only made in limited quantities.

Some of the checking equipment is made by the establishments themselves (special templet rules, set squares, rollers, internal screw gages, etc.), and in violation of elementary principles, often checked by means of instruments which these gages are being made to check.

At present the majority of establishments have organized their own lapping and repair of end gages; it is, however, very difficult to obtain microabrasives for the final polishing of faces even by paying cash for them. It is true that in the journal "Measurement Techniques" No. 1 of 1959, instructions are given on methods for their preparation , but, of course, it is preferable to produce them in a special plant instead of making them under primitive conditions in each workshop.

Many establishments have universal measuring equipment whose base plates are made of hard alloys and require diamond powders for their lapping, yet it is almost impossible to obtain these powders.

Neither is it any easier to obtain spare parts for opticomechanical instruments.

The problems of centralized manufacture of equipment for checking measuring instruments, spare parts and units, and means of lapping gages and instruments should be taken up by ministries, departments, Sovnarkhozes, and establishments concerned, especially by instrument-making plants.

INFORMATION

RADIO MEASURING EQUIPMENT AT THE GERMAN DEMOCRATIC REPUBLIC EXHIBITION OF ELECTRONIC INSTRUMENTS

V. P. Rynkevich

At the electronic and nuclear instruments exhibition of the German Democratic Republic held in Moscow in July, 1959, many exhibits were devoted to radio measuring instruments, whose manufacture has achieved considerable success in the GDR.

Particularly interesting were the instruments for measuring pulses, signal generators, field strength meters, and instruments for measurements in the microwave range.

Pulse Measuring Instruments. Pulse-measuring oscillograph OG-1-8, developed by the "Kopenick" plant, is a universal instrument. It can deal with periodic phenomena with frequencies from 20 cps to 3 Mc and static or periodic pulse sequences with pulses of a duration of 0.1 μsec to several milliseconds. A sawtooth scanning generator is used which provides both single-pulse and continuous scanning operations. Scanning of a duration of 3.2 μsec to 50 msec can be provided. A way of delaying scanning with respect to trigger pulse by 2 μsec to 1 msec is provided. The instrument's cathode-ray tube is 120 mm in diameter; special terminals giving direct access to the plates or the control electrode are provided. The plate input capacity is less than 10 $\mu\mu$f.

The oscillograph is supplied with a set of accessories and attachments, including a photographic attachment, a device for tracing oscillograms, a delay line of 1 μsec, a baffle diaphragm, a viewing tube, a projection attachment, a measuring grid with a light filter, coaxial couplers, a scale marking generator, a pulse amplifier IV-10 and a wideband amplifier BV-8.

By means of the marking generator which provides markers on the oscillograph screen, voltages of any waveform can be accurately measured.

The pulse amplifier IV-10 is a separate instrument, designed for amplifying periodic and aperiodic pulses of any polarity with a frequency spectrum of 5 cps - 7 Mc. The continuously controlled gain has a top value of about 1000. Its input capacity is 22 $\mu\mu$f and input resistance 1 meg.

Square-wave generator RWG-2 is designed for testing, in conjunction with the oscillograph, wideband amplifiers, as video-channel amplifiers in television. The input of the amplifier under test is fed from the output of the generator with square-wave pulses with a duty factor of $1 \pm 10\%$ and the output of the amplifier is connected to the wideband oscillograph. The frequency properties of the amplifier are judged by the shape of the voltage displayed on the oscillograph screen. Square-wave oscillations are generated by a symmetrical multivibrator, whose frequency can be adjusted between 50 cps and 500 kc and synchronized with an outside signal. Steep pulse edges are provided by a special pentode stage which reduces the pulse rise time to less than 80 mμsec. The output amplitude of the generator across a load of 10 kilohm can be adjusted between 0.1 and 3 v.

The calibration marks generator MS-10$_s$ of the "Kopenick" plant is of an original design. The voltage of a stable quartz generator of 1 Mc is transformed into a sequence of pulses whose repetition frequency is divided several stages. The output pulses of the dividing circuit are used as strobe pulses and fed to the selecting stage where they separate from the basic sequence pulses whose phase is determined by the quartz generator, and repetition by the division ratio. Thus at the generator output, control pulses are produced which are stable in phase, can have any polarity, and are of less than 200 mμsec duration, as well as time-marking pulses of approximately 1.2 μsec duration. The repetition period of the output pulses can be changed in steps from 1 μsec to 8 msec. The

amplitude of the control pulses and time marks is,respectively, 20 and 12 v (for positive pulses with a load of 200 ohm and for negative with 300 ohm). The instrument includes an oscillograph with a 3 cm screen for checking the operation of the dividing circuit.

The instrument for measuring small time intervals MT-1 can be used for measuring the operation of relays, the duration of single electrical pulses,and the duration of light pulses. The measurement principle consists in determining the voltage across a capacitor, which is charged during the time whose duration is being measured. The pointer indicating instrument is calibrated in milliseconds and provides measurement of time intervals from 0-1500 msec with an error not exceeding ± 2%.

Spectrometer SPM-1 is designed for investigation of high frequency signal spectra in the range of 2,500 to 10,000 Mc. The instrument operates on the principle of signal frequency transformation with an intermediate frequency set at 37.5 Mc. The spectrum under observation is seen on an oscillograph screen which receives simultaneously calibration pips (at 1.5 or 50 Mc) whose frequency is stabilized by a quartz oscillator. The error in determining the frequency does not exceed 10^{-4}.

Measuring Generators. The "VF" establishment has developed for the wavelength range of 9-100 cm three standard signal generators. Generator EMS-1 covers the range of 9-15 cm, EMS-2 from 15-30 cm,and EMS-3 from 30-100 cm. The high frequency part of the generators works with transistors and uses coaxial lines as resonators. Provision is made for frequency modulation at 400 cps. The output voltage is controlled between 2 μv and 10 mv with an accuracy of ± 15% ±1 μv. The frequency stability is better than 0.1% with changes in the supply voltage of 1%. The incorporated frequency measuring devices provide an accuracy of 0.5 - 1.5%, according to the range used.

The standard signal generator EMS-262 of the "Rafena" plant works in the range of 2.5-3.5 and 8-150 Mc and is used for testing intermediate frequency amplifiers, filters, and radio receivers. The instrument incorporates a push-pull oscillator. The output voltage across a load of 70 ohm can be adjusted between 1 μv and 100 mv with an error not exceeding ±10%±1μv. For amplitude modulation the generator has a 1000 cps oscillator. External modulation is possible by means of an audio frequency oscillator. The error in the frequency of the output signal does not exceed 0.5%.

Generator PG-1 is designed to test radio and television receivers in the frequency range of 5-235 Mc. The instrument produces a frequency modulated voltage in the range of 10 μv-50 mv. The modulation is internal but external modulation can also be applied. Frequency modulation is attained in a circuit consisting of germanium diodes which act as variable capacitors. The modulating frequency is 1000 cps ±15%. The generator provides a frequency accuracy of not less than ±1% and voltage accuracy of ±30% ±10μv.

Test generator M2746 has a wide field of application. This instrument generates voltages in the range of 95 kc-18 Mc adjustable between 2μv and 100 mv. The frequency accuracy is ±0.1%. The output voltage can be amplitude modulated at 400 cps, and the modulating voltage is taken out at separate terminals. The instrument can also be used for measuring voltages, since it contains a v-t voltmeter which provides measurements in the limits of 0.1-2v. It can also measure capacitance between 2 and 10,000 $\mu\mu$f and inductance between 0.2 and 2,800 μh by means of a resonance method. The error of measurement does not exceed ±5%.

Noise generator RSG-2 is designed to measure the sensitivity of receivers and amplifiers. A saturated noise diode serves as a source of noise and produces noise in the range of 10-300 Mc. The sensitivity is measured by comparing the internal noise of the equipment under test with a noise signal of a known value. The generator is calibrated in kT_0 units (1 $kT_0 = 4 \cdot 10^{\pm 21}$ w·sec) in the range of 0-75 kT_0. The noise energy is changed by varying the heater current of the diode.

Field Strength Meters. Two field strength meters made by the "VF" plant were exhibited. Instrument FSM-1 is designed to measure field strengths in the range of 0.1-30 Mc and consists of a superheterodyne receiver with a frame aerial, and a diode voltmeter. The entire range is covered by six aerials. The indicating instrument is calibrated in decibels and has two scales, a linear one (14 db) and a logarithmic one (60 db). The error of measurement does not exceed ± 2 db. By means of this instrument field strengths of 2-10 μv/ m to 100 mv/m are measurable.

Instrument FSM-2 covers the range of 20-100 Mc. It uses a wideband dipole antenna. The double conversion superhet receiver provides a sensitivity of 0.5μv/ m.

Decimeter-Range Instruments were represented by standard signal generators (which have already been described), instrument lines, voltmeters, and frequency meters. For frequency measurement six instruments were shown, which covered the range of 300 to 3,000 Mc.

Instrument line DML-122 of the "Rafena" plant is designed for the range of 15-30 cm. The inherent error of the line is less than 5%, the accuracy of reading 0.1 mm, and the impedance 70 ohm. Similar instrument lines DML-112 and DML-113 cover the ranges of 500-3500 and 400-3500 Mc respectively.

Measuring detectors of the "Rafena" plant are designed to measure the output power of generators whose output signal has no higher harmonics, to an accuracy of ± 20 to 30%. Detector KMD-616 covers the range of 1000-1765 Mc and detector KMD-615 the range of 1200-1460 Mc. The measuring detectors consist of a coaxial line segment terminated in a resistance with a minimum reflection. The internal conductor is connected through a capacitor to a detector consisting of crystal diodes; the detected current is measured by an instrument incorporated in the set.

The decimeter voltmeters serve to measure power and voltage in coaxial lines in the range of 1 kc to 1000 Mc. The impedance of the voltmeter type DVM-106 is 70 ohm and that of DVM-107 is 60 ohm. The instruments consist of diode probes and the main body of the voltmeter. A set of two probes provides a range of 0.25 to 250 v with a maximum error of 28% at 1000 Mc.

Computer frequency meter type 3006 is an example of the new type of measuring instruments which use computer techniques for simplifying measurements. The measured signals are transformed in the instrument into pulse sequences of the same frequency and fed to the gating circuit, which is controlled by pulses from a standard 100 kc quartz oscillator. These controlling pulses can be reduced by division to frequencies of 100, 10, and 1 kc, and 100, 1 and 0.1 cps. The signal pulses are passed through the gating circuit for a period determined by the controlling pulses and fed to a decade trigger counter. If this period of time amounts to 1 second, the computer counts the frequency directly in cycles per second which is displayed by illuminated numbers on the front panel. The instrument can be used for measuring time intervals, counting the number of pulses, and also as a source of standard frequencies or calibration pips. Its frequency range is 0-1 Mc, and the frequency accuracy is determined by the stability of the quartz oscillator. Measurements can be made singly or to automatically repeat themselves every 0.5-10 seconds. The instrument uses counting decades type 8100 (for 100 kc) and 8101 (for 1 Mc). The resolution time of decade 8101 is 0.6 μsec, thus providing the means for investigating rapid processes.

THE POLISH INDUSTRIAL EXHIBITION*

The Polish Industrial Exhibition was held in Moscow in September, 1959, at the Gor'kii Park of Culture and Rest.

The exhibition, which occupied some 18,000 m², showed the achievements of Polish industry in the last 15 years and indicated the development plans for the expansion of Polish exports.

The exhibition included equipment for the mining, chemical, engineering, light, and food industries, building materials, measuring instruments, electronic apparatus, radio and television installations, radio receivers, television sets, optical instruments, medical equipment, etc.

Gliders, sports airplanes, automobiles, agricultural and building machinery, and shipbuilding models were also exhibited. One of the pavilions was dedicated to man and his life.

In Poland there are a number of establishments which make electronic measuring instruments. The exhibits included instruments made by the Elpo plant in Warsaw, the T-12 electronic instruments plant in Warsaw which

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* The article was written from the materials presented by Z. Sokhatskii, M. Lapinskii, E. Kalinskii, A. Koval'skii, and E. Naglovskii.

makes scientific apparatus, the Zopan factory in Warsaw, the Eurica industrial cooperative in Warsaw, the Radiotechnika industrial cooperative in Vraclav, and the Wielkopolskie Zaktady Teletechniczne T7 in Posnan which makes communication equipment.

These establishments exhibited a large variety of measuring instruments, including adjustable autotransformers, stabilized power packs, bridges for measuring RLC and frequency, generators of sinusoidal square-wave and spiral voltages, standard signal generators, megohmmeters, voltmeters, galvanometers, oscillographs, synchroscopes, timers, Q meters, frequency-modulated generators, output meters, nonlinear distortion meters, standard resistors, potential dividers, computers, electronic switches, etc.

The exhibits of the Warsaw Polytechnical Institute were of interest, including a model of a digital display Q meter, for measuring the Q factor of coils in the range of 1 kc to 10 Mc; the results are recorded on a special computer. The principle of operation of this meter consists in measuring the number of decaying oscillations of a parallel tuned circuit when its capacitor is discharging after having been charged to a predetermined voltage.

The same department of the Polytechnical Institute developed several models of frequency meters with counters.

The electroacoustical department exhibited an ultrasonic fault detector for locating flaws in materials.

The ultrashort wave department showed a model of a ferrite circulator used to separate electromagnetic waves propagated in opposite directions along a waveguide (for instance, a direct and reflected waves). The reflected wave is directed into a separate transmission line completely separated from the main line. By means of this circulator it is possible to measure the reflection factor of electromagnetic waves in the three-centimeter range.

The wire communication department exhibited several telephone carrier systems working on frequencies up to 600 kc and a model of a device for simulating and measuring the distribution of energy in power transmission lines.

The electronic measurements department of the Vraclav Polytechnical Institute is developing electronic measuring instruments with a digital display, since they provide a considerable advantage in indicating directly the measured value.

The apparatus and equipment for working with radioactive elements merited special attention. They included six manipulators which provide the possibility of investigating radioactive elements with complete safety for the research personnel. The distinctive characteristic of these very simple devices is their ability to perform all the required operations with the preparations under investigation (weighing, observation of reactions, mixing, etc.).

The exhibition included various containers, tables for working with radioactive elements, manipulation chambers, and a large number of complex electronic instruments.

The Institute of Nuclear Studies has developed a number of instruments for the measurement of the intensity of radiation and other quantities characterizing radioactive substances.

A large space in the exhibition was occupied by ultrasonic instruments (fault location devices, concrete testers, etc.). Ultrasonic fault locator type D18R provides the possibility of detecting defects in metals and ceramics in practically all building components. Owing to the use of a wide range of frequencies and a large number of ultrasonic crystal converters of various types, it becomes possible to detect both defects of an area smaller than 0.5 mm^2 and defects in constructional components of various shapes.

Concrete tester V 16 which serves to determine the properties of concrete and concrete constructions by measuring the speed of propagation of ultrasonic waves was of considerable interest.

The Polish optical factory (Warsaw) exhibited a wide range of microscopes and other complex optical instruments.

Projecting microscope MR-2 which provides an amplification of 500 and 1000 and has a glass screen of 160 mm in diameter, is used for mass-production measurements of small articles and also of fibers with an accuracy of 0.001 mm. The microscope is equipped with a cruciform stage and its own source of light supplied

through a transformer. Owing to a convenient location of the screen it is not tiring to work with the microscope, which is an advantage in mass-production measurements.

A set of laboratory instruments was of considerable interest; it included analytical balances, pH meters, driers, thermostats, calorimeters, viscosimeters, as well as meteorological and geodesical instruments.

The industrial measurement equipment which was shown by the "Varimex" establishment is designed for measuring nonelectric quantities. This group includes flow and liquid meters, and pressure and temperature gages.

Among the liquid meters were included domestic and commercial water meters of all sizes for hot and cold water, single and multi-jet, dry and wet operated. Water meters are made for discharges of 3 to 20 m^3/hr (dimensions of $\frac{1}{2}$ -$1\frac{1}{2}$ ").

Commercial water meters of two types are used, those with a vertical vane of 50-150 mm and with a horizontal vane of 400 mm.

Differential dial pressure gages are used both as indicating and as indicating and recording instruments. Integrating instruments can also be used. Indicating and recording instruments are also made for corrosive media for static pressures up to 0.5 atm. If required, each instrument can be fitted with a potentiometric device for remote recording and a set of signalling contacts.

A float differential manometer is another type of flow meter which can be used with static pressures up to 200 atm. It can be used as an indicating, indicating and integrating, as well as indicating, recording, and integrating instrument and it can be equipped with various transducers.

Ionization vacuum gages, reading down to 10^{-7} mm Hg, serve to measure high vacuum.

A compensation type micromanometer with an error of measurement of 0.03 mm Hg and two types of micromanometers with an inclined tube were also shown at the exhibition.

Among the instruments for measuring, checking, and recording temperature there were exhibited not only mercury-in-glass thermometers, thermocouples, thermistors, and radiation pyrometers, but also various single and multicurve recording instruments.

Electronic analyzers of CO_2 and $CO + H_2$ used for indicating the percentage content of these gases in the combustion products of solid, liquid, and gas fuels were of interest as well as the electrical analyzers used in the mining industry. A portable methane meter M-4 serves to measure the percentage content of that gas in air and is adapted for use in coal mines. This meter has a double scale reading from 0-0.5% CH_4 and 0-5% CH_4. The measurement error is ± 4% of the full scale deflection. The external dimensions of the set are 165 × 80 × 120 mm and its weight 2 kg.

THE CZECHOSLOVAK EXHIBITION OF MEASURING EQUIPMENT AND ELECTRONICS

G. L. Grin

The Czechoslovak Exhibition of Measuring Equipment and Electronics, briefly reported in the last issue of this journal, has now come to an end.

The attention of the visitors was centered on the automatic vibration apparatus TURBO-4 which received a gold medal at the Brussels International Fair in 1958. The apparatus is designed for dynamic analysis, testing for fatigue, and measuring the damping factor of turbine blades. It can also be used for testing other components of machines such as bicycle frames, various levers, connecting rods, etc. The device consists of a controllable vibrating base assembled in two parts: the base and the electronic unit which controls it. The base is actuated by

a powerful kilowatt v-t amplifier. The latter is either tuned automatically to resonate with the component under test or is driven by an RC oscillator with an adjustable frequency (20 cps to 30 kc), amplitude (up to 400 v, 2.3 amp), and phase (± 180°). The electronic control unit, in addition to the amplifier and audio oscillator, also contains a double beam cathode-ray oscillograph, a v-t voltmeter, controlling and measuring instruments, regulating and stabilizing units, and power supplies. The device has an electronic stroboscope and a powerful adjustable rectifier for magnetizing the driving coils of the vibrating base.

Another exhibit which also obtained a gold medal at the International Fair was the Tesla (Brno) electron microscope which has excellent technical characteristics. It provides magnifications of 10,000-30,000 and has a resolving power of 20 A. The instrument has small dimensions, weighs only 130 kg, and stands easily on a laboratory table.

Numerous electronic measuring instruments made by the Tesla plant for the needs of the radio and electronic industry were among the displays on view in the exhibition hall. They included various standard signal generators, RC generators, secondary frequency standards, universal ac and dc bridges, electronic millivoltmeters, Q meters, nonlinear distortion meters, service instruments for radio and television workshops, etc. A set of instrument waveguide lines for the decimeter range was particularly outstanding. The set consists of units which measure the standing wave coefficient, the impedance of resonant cavities, power and attenuation in the range of 2 600-3 950 Mc and a similar device for coaxial systems working in the range of 1 700-4 000 Mc.

The type K552 cathode-ray oscillograph made by the Krizik plant for observing simultaneously five different channels was just as interesting. The diameter of the screen of this multi-tube oscillograph is equal to 120 mm. The nuclear particle counter VM 353 is of great interest. This instrument is designed for working with radioactive emissions in physical laboratories, medicine, and industry. The instrument has a resolving time of 10 μsec, and its counting capacity is 10^7 with the three first decades of the computer consisting of double-triode trigger units with ten neon indicators in each decade which provide a simple decimal count. The last four decades are displayed in illuminated and magnified numbers by the electromechanical counter. The instrument also includes an adjustable (rough and vernier) stabilized high-tension (2 000 v) rectifier for supplying the Geiger-Müller counter. The weight of the instrument is 30 kg and its external dimensions are 490 × 275 × 340 mm.

The precision audio frequency generator VM269 is of great interest. It covers a range of frequencies from 11 cps to 22 kc in seven bands. Its frequency accuracy is 0.5% and when checked by means of the incorporated oscilloscope and quartz oscillator it is $\pm 10^{-4}$. The instrument provides a nonlinear distortion factor of less than 1% and contains a v-t voltmeter and stepped and continuous attenuators for the output signal. The weight of this 23-tube instrument is about 60 kg.

At the exhibition there was a large number of measuring instruments specially made by the Tesla plant for wire systems. They include audio beat frequency oscillators type 12XG014 with a frequency error not exceeding 0.1%; an infrasonic oscillator type 12XG017 with a range of 1.5-300 cps and a power of 3 w. The latter instrument is designed for measuring transfer functions of relay communication lines. Other instruments included lever indicators 12XN012 , 12XN013 and 12XN023 for the frequency range of 20 cps to 2 Mc, and level values of −9 to + 2.5 neper with an error not exceeding ± 0.05 neper; attenuation meters up to 15.21 neper type 12XV000 and other instruments for balanced and unbalanced lines with impedances of 600 and 150 ohm and frequencies up to 1 Mc; an impedance bridge type 12XJ009 using Glützmacher's circuit, which also measures the phase angle with an error not exceeding ± 2%; a crosstalk measuring set type 12XX004; distortion meter 12XX029; an instrument for measuring small intervals of time type 12XX011A covering in six bands a range of 10 μsec to 3 sec with an error of ± 5%.

Electricity meters of the Krizik plant, well known all over the world, were also exhibited. In addition to the single-and three-phase power and wattless power meters, the two-rate and maximum type meters ET 3-4, D, M, HM with a measuring period of 15, 30, and 60 minutes, were exhibited.

The Krizik plant also exhibited a ferroscope type F563 for comparing magnetic parameters of various magnetically soft materials including permalloy and electrical steel. The samples of the materials are placed inside coils (150 mm in diameter) and their characteristics are observed on the screen of a cathode-ray tube in the control unit.

Among the electrical measuring instruments of particular interest was the series of laboratory grade 0.2 instruments produced by the "Metra" plant which included microammeter DLL with a range of 20 μa. Two special

sets for checking pointer instruments; the type QSLK set for dc instruments, and the one for ac instruments are of interest. So is the special gaussmeter which uses Hall's effect for its operation. The instrument's transistorized probe has dimensions of only 3 × 1.5 × 0.4 mm. The error of this instrument does not exceed 2.5%. The multipen ink recording instruments type Rg 140, Rg 280, and Rg 380 are of interest. The latter provide simultaneously a record of six different processes on a chart 300 mm wide with each process occupying a separate band, 45 mm wide when six grade 2.5 records are made and 100 mm wide when three grade 1.5 records are made. The world's smallest grade 5 moving coil instrument was also exhibited. The scale of this instrument is 13 mm long and its external dimensions are 22 × 22 × 16 mm and its weight 16 g. Its full scale deflection is 50 µa and the coil resistance 1200 ohm. The body of the instrument is made of a transparent plastic material.

A series of round scale switchboard instruments grade 1.5 with a deflection angle of 300° were also exhibited. The series includes moving iron ammeters, voltmeters, three-phase meters, synchronoscopes, ferrodynamic wattmeters, frequency meters, moving coil voltmeters and ammeters, differential detecting voltmeters, etc. These instruments are mounted in square cases. They are made in four sizes with a side equal to 70, 90, 110, and 140 mm. The zero adjuster is placed in the middle of the glass front. The "Metra" plant also demonstrated miniature standard grade III cells for electronic automatic potentiometers and other devices. The cells are cylindrical in shape with a diameter of 22 mm and 44 mm length.

In another section of the exhibition, products of the electrical clock industry made by the Prague "Electrochas" plant were exhibited. Among the numerous time stations, timekeeper clocks, master clocks, etc., there were many versions of clock and signalling devices for schools, sports grounds, hockey, football, basket ball, clocks for recording the arrival of carrier pigeons at the starting point, etc. Side by side with these articles the products of the optical plant "Meopta" were shown, including a miniature level type NK30, a trinoscope, a polarimeter of the "Metra" plant (model 410) a refractometer, a movie camera for photographing images seen on a cathode-ray tube screen, etc.

A model of the "Dyustra" crane scales which work with a special torsion electromagnetic transducer. The error of this scale which works in ambient temperatures of −30 to +80°C does not exceed ± 0.25%. Such scales are made in different models for maximum loads of 200 kg to 20 tons.

A prominent place was allocated to the pneumatic and electronic instruments made by the "Regula" plant for remote automatic recording, control, measurement, and signalling of technological processes. These instruments included high precision recording gas analyzers, dial scales, manometers, flowmeters, level meters, etc. The "Prima" plant demonstrated a series of water meters in plastic bodies for nominal discharges of 3-20 m^3/hr with a 5 liter/hour sensitivity threshold and maximum error of ± 5% and 150 liter/hour with an error of 2%.

The production of the plant "Kovostav" was represented at the exhibition by special instruments for the textile industry, including various tensile stress testing machines with adjustable tensioning speeds from 50 to 300 mm per 20 seconds, hygrometers for measuring moisture in cloth and yarn, a humidity-controlled drying oven with an analytical balance, torque meters, machines for testing the durability of threads and cloth, etc.

In a separate hall the products of the Czechoslovak radio and electronic tube industry were demonstrated. Various radio and television tubes were shown, including kinescopes, magnetrons, x-ray tubes, transistorized instruments, ionization instruments, klystrons, quanticons (television transmitting tubes 20 mm in diameter for industrial television and telemetering). The latest in radio receivers, television sets, tape recorders, and transistorized portable and automobile radio sets were also shown.

A CONFERENCE OF ELECTRICAL CIRCUITS USING RECTIFIERS

V. P. Sigorskii

In June, 1959, a conference was held in L'vov on electrical circuits which use rectifiers; the conference was called by the Institute of Engineering and Automation of the Acad. Sci. Ukrainian SSR in conjunction with the Moscow Lenin Electrotechnical and L'vov Polytechnical Institutes. The conference was attended, in addition to the organizing bodies,by more than 40 academic scientific research institutes, schools of university standing, industrial institutes, design offices, and leading plants of Moscow, Leningrad, Kiev, L'vov, Novosibirsk, Tomsk, Tashkent, Riga, Gor'kii and other cities of our country.

At the conference 46 papers were read and discussed dealing with engineering methods of calculating and designing electrical equipment with rectifying elements (automation equipment, electrical measuring instruments, rectifiers and converters of electrical power, electronic computers, communication apparatus, etc.), the development of new rectifying elements, the study of the physical processes in the rectifiers, and improvements in the methods of analyzing electrical circuits with rectifiers.

Several papers dealt with the application of rectifying elements in automatic control and measuring instruments. Kh. M. Zhelikhovskii analyzed automatic insulation checking circuits which used rectifiers. Ya. S. Averbukh described universal measuring instruments with semiconductor rectifiers developed by the Kiev "Tochélektropribor" plant. P. B. Usatin dealt with special rectifying circuits for measuring insulation resistance of ac circuits under tension and with the use of rectifying instruments for measuring ac current and voltage of 0.5-1.5 cps.

A paper on the application of transistors in automation and remote control of railroads was read by M. M. Kirillov.

V. I. Stafeev and É. I. Karakushan discussed the magnetic control of currents in diodes. Magnetic diodes have been developed whose voltage and current change abruptly in magnetic fields. Magnetic diodes can be used both in instruments for measuring permanent and especially alternating magnetic fields and also for amplifying electrical signals.

D. N. Nasledov, N. N. Smirnova, and B. V. Tsarenkov examined the prospects of using junction and point-contact diodes made of gallium arsenide in view of the advantages they have as compared with silicon diodes.

N. S. Yakovchuk and I. I. Rodicheva analyzed in their paper three instruments which are used for testing semiconductor diodes and measuring their parameters.

In its resolution the conference noted the importance for the national economy of the technique of transforming and rectifying electrical currents, especially in connection with one of the most important tasks of the Seven-Year Plan — production automation.

The conference brought to light the defects in coordination of scientific and research work and mutual information and requested the editorial boards of several journals including "Measurement Techniques" to devote more space to questions of electrical rectifiers.

The conference considered it imperative to intensify the assimilation by our national economy of the production of the most important equipment for the transmission of power by direct current over long distances, electronic devices for production automation, electrification and automation of railroads, etc.

THE COMMITTEE OF STANDARDS,
MEASURES, AND MEASURING INSTRUMENTS

A CHECKING SCHEME AND MEASURING APPARATUS IN THE

SPHERE OF ANGULAR MEASUREMENTS

In June, 1959, the Experts' Council of the Committee of Standards, Measures, and Measuring Instruments examined the scientific and research work carried out by four institutes of the Committe (VNIIM, the Sverdlovsk branch of the VNIIM, VNIIK and NGIMIP) in connection with their combined investigation of "The development of a system for transferring dimensions in the sphere of angle measurements and the production of measuring equipment which will fill the gaps in this system."

The aim of this work was to provide the equipment required for preserving uniformity in measuring angles and to develop a testing technique in this sphere.

Contrary to linear measurements a method of reference standards did not exist in angular measurements, neither was there the equipment or technique which could provide the accuracy required at present in comparing large angles with small ones, nor was there a unified method of checking goniometers.

Higher accuracy in measuring angles required by the industry also pointed to the necessity of improving the basis of angular measurements.

The general direction of the work and the basic problems to be tackled were formulated in the following manner.

The task of the VNIIM was the production of an apparatus for the highest grade of the checking scheme, namely, for a reference method of producing flat angles. This task was shared by the NGIMIP.

VNIIK's task included the development of the technique of checking goniometers, graduated in 6, 10, and 30 seconds of arc by means of polyhedrons and the determination of the accuracy of the interference method of measuring angles and the sphere of its application.

The Sverdlovsk branch of the VNIIM developed a testing device for angle gages and angle measuring instruments.

In designing the testing equipment it was necessary to analyze the aggregate error of measurement in transferring the value of the angle to the gages and angle measuring instruments. This part of the work was carried out by the Sverdlovsk branch by using the materials and test results obtained in Sverdlovsk and other institutes of the Committee. A large part of the work of the branch deals with the analysis of the accuracy of measuring angle gages (blocks) on various instruments used at the present time for certifying sets of these gages. Next the problem of transferring the value of the angle by means of angle gages of two grades and three categories, or standard polyhedrons and angle measuring dial instruments was systematically analyzed. As the result of this work, the branch recommended a test method based on obtaining the value of a plane angle by means of a polyhedron prism and auto-collimators. The testing method proposed by the Sverdlovsk branch is based on techniques and equipment which reproduce the angle with much greater precision than previously obtained by goniometric technique. The above method has its defects, and the department of basic units of the VNIIM has examined another testing method developed by the department.

The VNIIK started its work by developing a technique for testing goniometers with graduations of 6", 10", and 30" by means of polyhedron prisms. The effectiveness of this method was dictated by the long experience gained by our industry in using such prisms for checking angles of rotation. These methods have been used for checking instruments of the type of ODG and ODS. However, a unified method of measuring goniometers did not

exist. The research workers who dealt with this problem developed an efficient method of checking goniometers and compiled instructions for the testing of goniometers with graduations of 6", 10", and 30". The polyhedrons (with 6, 8, and 12 faces) were certified by means of a goniometric device based on the circular measuring machine in the possession of the VNIIK.

Another task of the VNIIK consisted in "Determining the accuracy of the interference method of measuring angles and the sphere of its application." The task consisted in producing an apparatus for the interference method of measuring angles and determining the possibilities of this method. This involved developing techniques for measuring polyhedrons by means of the available equipment and evaluating the possible accuracy of such methods. For the solution of the first part of the problem a Kesters interferometer available at the VNIIK was used. By placing near the output slit of the instrument an additional lens and using a standard eyepiece micrometer AM9-2 an apparatus was made up which consisted of the interference attachment of Kesters' instrument, a device for measuring in the horizontal plane, and the goniometer type GS used as a turntable for the polyhedrons. As a result of calibrating three pairs of 6-, 8-, and 12-sided prisms it was found that, if the difference between the angles of the two polyhedrons being compared does not exceed 2" such angles can be measured with an accuracy of several tenths of a second.

The conclusions indicate conditions under which it is possible to attain in the absolute method of measurement calibration accuracy of the order of 0.2"; for the absolute method of measurements the maximum error of measuring polyhedrons was taken as ± 0.4".

The devices used for horizontal measurements (i.e., the additional lens and the micrometer) serve to improve the conditions for measuring fringes on Kesters' interferometer without further modifications.

VNIIM's work consisted in producing a device for the reference method of reproducing angles. The method consists in calibrating a polyhedron prism by means of two independent auto-collimators, which are placed in such a manner that their optical axes are perpendicular to the reflecting faces of the prism, and the angle between the auto-collimators is equal to the nominal value of the angle between the perpendiculars to the faces. In order to utilize the advantages of this method as compared with other modern methods to the fullest extent, the experience of VNIIM's previous work with auto-collimators and in certifying measuring prisms, as well as the peculiarities and defects of the equipment used in foreign metrological establishments, was taken into consideration when the angle measuring equipment was designed. Thus the VNIIM auto-collimators use special long focal-length objectives which combine high precision with ease of operation.

The basic and most complicated part of the work was the making of standard prisms according to a specially developed technique. Five high precision quartz prisms were made (three with 36 sides and two with 24 sides). Of the five prisms, three have been used in the VNIIM equipment . As the result of this work an apparatus was made for a reference method of measuring angles which consisted of two auto-collimators with teleobjectives, two 36-sided and one 24-sided prisms made of fused quartz, an optical dividing head (the turning device for the polyhedrons) and a massive iron base. Absolute and relative measurements were made with this equipment.

A comparison of the absolute measurements of the two monolithic 36-sided prisms of the VNIIM with those obtained by the National Bureau of Standards, USA, in calibrating their steel sectional 24-sided prism (the basic NBS standard) showed that the root-mean-square error of a number of measurements for the No. 1 and No. 2 VNIIM prisms is 0.14" and 0.19", respectively, and for the NBS prism 0.22".

The calibration of the No. 1 and No. 2 prisms showed that the angles between their adjacent faces are more accurate that those of the NBS prism. Thus in the No. 1 and No. 2 prisms about half of all the angles have deviations from their nominal values not exceeding 1", in the first 36-sided prism only five angles have deviations up to 4" and in the second there is only one such angle, whereas in the basic NBS prism these deviations reach 8". In considering these results the VNIIM Scientific Council, which examined the report of the work done in this connection, was able to note that the equipment required for producing the basic standard of the checking system had been made by the VNIIM.

As a result of discussing the scientific research work done and the conclusions of the expert commission, the Expert Council adopted a detailed resolution in which:

1. It recognized the scientific research work done by the VNIIM, VNIIK, and the Sverdlovsk branch of the VNIIM as essential and of scientific and practical value. The research carried out and the equipment produced

provide an increased accuracy in angle measurements corresponding to the requirement for higher quality instruments, machines and tools.

2. Recommended approval of the auto-collimation method and equipment developed by the VNIIM as a reference method for producing the value of a plane angle.

In order to ensure that the VNIIM method and equipment are adopted in practice it was found necessary: a) to request the VNIIM to describe the technological method of making polyhedron prisms in the form of a manual; b) to mass -produce in the Novosibirsk plant under VNIIM supervision a small quantity of VNIIM auto-collimators for distribution to institutes of the Committee and 1st grade State Inspection Laboratories of Measuring Equipment; c) to make at the Novosibirsk plant, according to the technical conditions and technology of the VNIIM, polyhedron prisms for the auto-collimator equipment.

The Council recommended use of the interference method and equipment for measuring angles, developed by the VNIIK, for certifying graded standard polyhedron prisms, i.e., as an absolute method of calibrating polyhedrons next in accuracy to the reference method of producing a plane angle unit. In order to introduce into general use the VNIIK method and equipment, it was decided to request one of the optical plants to mass produce a small quantity of devices   of the VNIIK type for distribution to the Institutes of the Committee and 1st grade State Inspection Laboratories.

The Expert Council considers it necessary to entrust the VNIIM, VNIIK and the Sverdlovsk branch of the VNIIM to develop further, under the guidance of the VNIIM, the testing procedure proposed by the Sverdlovsk branch of the VNIIM in the following respects: a) to simplify the procedure by restricting, for instance, the classification of polyhedron prisms to four grades of accuracy (abolishing prisms of the 3rd grade), that of standard gages to the first two grades, inspection gages to two grades of accuracy, etc., b) to include in the checking procedure such fairly common measuring instruments as sine rules, telescopic quadrants, theodolites, Churikov's instruments, as well as indirect methods of checking by means of telescope calipers and inspection gages without a scale; c) to ensure adequate and clear characteristics, remembering that all the measuring devices, including the basic reference, must be specified by their limiting error, value of graduations and name (if it exists); d) the error of checking must not exceed 1/3 of the maximum error of the device being tested. If that rule cannot be kept, the increased error of checking, for instance, to 1/2 of the maximum error of the device under test, must be justified.

It was decided to entrust the VNIIM, VNIIK and the Sverdlovsk branch of the VNIIM to evolve a plan for the general adoption of the testing procedure, when it has been finally developed.

NEW STANDARDIZING DOCUMENTS FOR MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE

(Registered in July-August, 1959)

NEW STANDARDS

GOST 1845-59. Electrical measuring instruments. General technical requirements. Replacing GOST 1845-52 with respect to the general requirements, GOST 2261-43 except ratio meters and pyrometric millivolt-meters, and GOST 2930-45 with respect to the marking for denoting the system of instruments and various conventional notations.

GOST 2789-59 Roughness of surfaces. Replacing GOST 2789-51.

GOST 5641-59 Test and mark-off prisms. Replacing GOST 5641-51.

GOST 7760-59 Normal gages. Replacing GOST 7760-55.

GOST 8137-59 Wobble meters for gears. Replacing GOST 8137-56.

GOST 9181-59 Electrical measuring instruments. Packing requirements. Introduced for the first time.

GOST 9233-59 Electrical measuring instruments. Spiral springs made from tin-zinc bronze. Introduced for the first time.

GOST 9242-59 Light filters for signalling in transport. Methods of measuring color and the transmission coefficient. Introduced for the first time.

GOST 9244-59 Hole gages with graduations of 0.001 mm. Technical requirements. Introduced for the first time.

GOST 9245-59 DC potentiometers, measuring. Introduced for the first time.